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THE PSYCHOLOGICAL REVIEW

THE CONFLICTING PSYCHOLOGIES OF LEARNING —A WAY OUT[1]

BY CLARK L. HULL

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INTRODUCTION

One of the most striking things about the present state of the theory of learning and of psychological theory in general is the wide disagreement among individual psychologists. Perhaps the most impressive single manifestation of the extent of this disagreement is contained in 'Psychologies of 1925' (14) and 'Psychologies of 1930' (15). In these works we find earnestly defending themselves against a world of enemies, a hormic psychology, an act psychology, a functional psychology, a structural psychology, a Gestalt psychology, a reflexology psychology, a behavioristic psychology, a response psychology, a dynamic psychology, a factor psychology, a psychoanalytical psychology, and a psychology of dialectical materialism—at least a dozen.

No one need be unduly disturbed by the mere fact of conflict as such; that in itself contains an element of optimism, since it indicates an immense amount of interest and genuine activity which are entirely favorable for the advancement of any science. What disturbs many psychologists who are solicitous for the advancement of the science of psychology is

[1] The substance of this paper was read as a portion of the symposium on 'Psychological theories of learning,' at the Pittsburgh meeting of the A. A. A. S., December 28, 1934.

The writer is indebted to Dr. Robert T. Ross for the material appearing in notes 7 and 8. Dr. Ross has also read and criticized the entire manuscript. Professor Max Wertheimer and Dr. George Katona also read and criticized an early form of the manuscript.

that of which these disagreements are symptomatic. To put the matter in an extreme form: if all of these twelve psychologies should be in specific disagreement on a given point, then at least eleven of them must be wrong, and in such a welter of error the twelfth may very well be wrong also; at all events, it is difficult under such circumstances to see how all can be right about everything.

The obvious implication of this general situation has recently called out a timely little book by Grace Adams (1) entitled, 'Psychology: science or superstition?' In this work she points out what we all know only too well—that among psychologists there is not only a bewilderingly large diversity of opinion, but that we are divided into sects, too many of which show emotional and other signs of religious fervor. This emotionalism and this inability to progress materially toward agreement obviously do not square with the ideals of objectivity and certainty which we associate with scientific investigation; they are, on the other hand, more than a little characteristic of metaphysical and theological controversy. Such a situation leads to the suspicion that we have not yet cast off the unfortunate influences of our early associations with metaphysicians. Somehow we have permitted ourselves to fall into essentially unscientific practices. Surely all psychologists truly interested in the welfare of psychology as a science, whatever their theoretical bias may be, should cooperate actively to correct this.

But before we can mend a condition we must discover the basis of the difficulty. A clue to this is furnished by the reassuring fact that persisting disagreements among us do not concern to any considerable extent the results of experiment, but are confined almost entirely to matters of theory. It is the thesis of this paper that such a paradoxical disparity between scientific experiment and scientific theory not only ought not to exist but that it need not and actually will not exist if the theory is truly scientific. It will be convenient in approaching this problem first to secure a little perspective by recalling the essential characteristics of some typical scientific procedures.

Four Typical Scientific Procedures

There are many approaches to the discovery of truth; for our present purposes these may be grouped roughly under four heads.

The simplest method of discovery is random observation —the trusting to chance that some valuable datum may turn up in the course of miscellaneous search and experiment. It is hardly conceivable that there ever will come a time in science when an experimenter will not need to be on the alert for the appearance of significant but unexpected phenomena. A classical example of the occasionally immense significance of such accidentally encountered observations is the discovery of the X-ray.

A second method of very wide and successful application in the search for truth is that sometimes known as systematic exploration. This seems to be the method advocated by Francis Bacon in his 'Novum Organum' (**2**). In modern times the discovery of salversan, by Ehrlich, illustrates in a general way this indispensable type of research procedure.

A third method widely employed in scientific investigations is that of the experimental testing of isolated hypotheses. Such isolated hypotheses often come as intuitions or hunches from we know not where; they occasionally appear in the form of prevailing traditions which are as yet inadequately tested by experiment. An example of the latter is the widespread belief that tobacco smoking interferes with the learning and thought processes (**9**).

A fourth procedure in the discovery of truth, and the one which particularly concerns us here, is found in experiments which are directed by systematic and integrated theory rather than by isolated and vagrant hypotheses. Such systematic theoretical developments are exemplified by relativity theory, chiefly in the hands of Einstein (**7**, 299), and by quantum theory (**20**), in the hands of a large number of individuals including Bohr, Rutherford, Heisenberg, Schrodinger, Dirac, and others. Perhaps the best-known investigation motivated by relativity theory is the astronomical observation whereby

it was demonstrated that the image of a star whose light rays had passed close to the sun showed a certain amount of displacement from its true position, conforming both as to direction and amount with deductions made from the theory (7, 370). Possibly one of the most striking recent experiments based on quantum theory is the well-known discovery and isolation of 'heavy' water, at Columbia University a few months ago, by Professor Urey.

Our special concern here is to point out that this fourth type of investigation, in addition to yielding facts of intrinsic importance, has the great virtue of indicating the truth or falsity of the theoretical system from which the phenomena were originally deduced. If the theories of a science really agree with the experimental evidence, and if there is general agreement as to this evidence, there *should* be a corresponding agreement regarding theory. An examination of the nature of scientific theoretical systems and their relationship to the fourth type of scientific procedure just considered should aid us in coping with the paradox presented by the present unfortunate state of psychological theory.[2]

Four Essentials of Sound Scientific Theory

It is agreed on all hands that Isaac Newton's 'Principia' is a classic among systematic theories in science. It starts with eight explicitly stated definitions and three postulates (laws of motion) (16, pp. 1–13), and from these deduces by a rigorous process of reasoning the complex structure of the system. Many persons who may not be overly familiar with the technical details of classical mathematical physics will be able to understand the essentials of such a system from our knowledge of ordinary Euclidian geometry, which as a systematic structure is substantially similar. In the geometries we have our definitions, our postulates (axioms), and, following these, the remarkable sequence of interrelated and inter-

[2] This emphasis on the fourth type of experimental approach is not to be understood as an advocacy of it as an exclusive method in psychology; neither is it being urged that theoretical considerations are paramount. Many approaches are necessary to produce a well-rounded science. Some temperaments will prefer one approach, some another, thus leading to a useful division of labor.

locking theorems which flow so beautifully by deduction from the basic assumptions. In a truly scientific system, however, a considerable number of the theorems must constitute specific hypotheses capable of concrete confirmation or refutation. This was eminently true of Newton's system. For a very long time the Newtonian physics stood this test, though finally certain important deductions from his postulates failed of confirmation, and it fell. Had Newton's system not been firmly anchored to observable fact, its overthrow would not have been possible and we would presumably be having at the present time emotionally warring camps of Newtonians and Einsteinians. Fortunately, we are spared this spectacle.

To summarize in a formal and systematic manner, it may be said that for a candidate to be considered as a sound scientific theory it must satisfy four basic criteria.[3]

I. The definitions and postulates of a scientific system should be stated in a clear and unambiguous manner, they should be consistent with one another, and they should be of such a nature that they permit rigorous deductions.

II. The labor of deducing the potential implications of the postulates of the system should be performed with meticulous care and exhibited, preferably step by step and in full detail. It is these deductions which constitute the substance of a system.

III. The significant theorems of a truly scientific system must take the form of specific statements of the outcome of concrete experiments or observations. The experiments in question may be those which have already been performed, but of particular significance are those which have not previously been carried out or even planned. It is among these latter, especially, that crucial tests of a theoretical system will be found.[4]

[3] As the reader examines these items it might be illuminating for him to consider the particular theoretical system which is his special aversion, and judge whether or not it passes each successive criterion. After having thus fortified himself, he might proceed cautiously to a similar examination of the system which he favors.

[4] For this reason it is especially desirable for the advancement of science that the proponents of theoretical systems publish the deductions of the outcome of as yet untried experiments. The failure of subsequent experimental verification of such de-

IV. The theorems so deduced which concern phenomena not already known must be submitted to carefully controlled experiments. The outcome of these critical experiments, as well as of all previous ones, must agree with the corresponding theorems making up the system.

Let us consider briefly some of the more important reasons why a sound scientific system should possess these four characteristics. Consider the first: If the postulates of an alleged system are not stated clearly they can hardly be known to the scientific public which may wish to evaluate the system. Moreover, if the postulates have never been explicitly written out by the sponsor of the system, the chances are high that they are not clear even to him. And, obviously, if the definitions and postulates of a system are not clear to the sponsor of the system, neither he nor anyone else can make specific and definite deductions from them.

Second, deductions must be performed with rigor because only in this way can their implications become known. Obviously, until the implications of the postulates are known they cannot possibly be submitted to experimental test; and unless the deductions are rigorous the experimental test will be futile because it will have no real bearing on the soundness of the postulates. Indeed, without rigorous deductions a would-be system is nothing more than a vague and nebulous point of view.

Third, the deductions must be related specifically to the concrete data of the science in question, since otherwise they cannot be submitted to the absolutely indispensable experimental test. It is here that scientific theory differs (or *should* differ) sharply from metaphysical speculations such as concern ethics and theology. Metaphysics does not permit this continuous check on the validity of the deductions, which largely accounts for the interminable wrangles characteristic of that literature. This criterion accordingly becomes in-

ductions should not be regarded as in any way discrediting the author. Instead, it should be considered merely a normal incident in the evolution of science. Fortunately, in such situations it is the hypothesis which is on trial, not the proponent's reputation as a seer.

valuable in distinguishing psychological metaphysics from scientific psychological theory. By this criterion much of what at present passes as theory in our literature must be regarded as metaphysical, *i.e.*, as essentially unscientific.

Fourth, the labor of setting up the critical experiments designed to verify or refute the theorems thus rigorously deduced from the postulates must be performed thoroughly and impartially because, once more, we shall otherwise lack the indispensable objective test of the truth of the system.

It scarcely needs to be added that there is nothing either radical or new in the above criteria of sound scientific theory; on the contrary, the program is conservative and respectable to an eminent degree. Indeed, it has been accepted in science for at least two hundred years. Our purpose is mainly to urge that we really put into practice what we, with the other sciences, have known for a very long time. This we evidently have not done; otherwise we would not be confronted with the glaring paradox of the wildest confusion in the matter of theory coupled with substantial agreement in the field of experiment.

Is Rigorous Theory in Psychology Possible?

No doubt many will feel that such standards of scientific theory may be suitable for theoretical physics, but that they are quite impossible in psychology, at least for the present. To take such a view is equivalent to holding that we can have no genuinely scientific theory in psychology. This is indeed conceivable, but if so we ought not to pretend to have theories at all. If scientific theories are really impossible in psychology, the quicker we recognize it, the better. There are signs, however, that the beginnings of a genuinely scientific theory of mammalian behavior are already on their way. Extremely promising examples of such achievements in intimately related fields have been published by Crozier (**3**) and by Hecht (**8**). The recent work of Gulliksen (**6**), in which he presents a genuinely rational equation for the learning curve, as distinguished from an empirically fitted formula, offers promise of a larger development in the field of mammalian learning.

It is probably not accidental that all three of the above studies are essentially mathematical. At present, on the other hand, the superficial appearance of the concepts regarding learning which are current among our theorists does not suggest ready mathematical treatment. And while this condition is probably more apparent than real, it serves to raise the important question as to whether rigorous logical deductions can be made on the basis of such quasi-mathematical concepts as have so far emerged from behavior experiments.

There is reason to believe that a genuinely scientific system may be constructed from such materials, and that the difficulty of making such theoretical constructs is not nearly so great as their rarity might lead one to expect. Obviously, the best evidence for such a belief is actual performance. Accordingly, the following section (pp. 501 *ff.*) of this paper is given over to the presentation of a suggested miniature scientific system based on typical quasi-mathematical concepts. This has been developed by means of a form of reasoning analogous to that employed in ordinary geometrical proofs. In it an effort has been made to conform to the criteria laid down above as necessary for a sound theoretical development. It is hoped that it will aid in making clear in some concrete detail the theoretical methodology here being advocated. Let us, accordingly, proceed to the critical examination of this miniature theoretical system in the light of our four formal criteria of what scientific theory should be.

At the beginning (pp. 501 *ff.*) there will be found a series of eleven definitions: of rote series, of the learning of rote series, of excitatory tendency, of inhibitory tendency, of spanning, of actual and of effective strength of excitatory tendencies, of remote excitatory tendency, of trace conditioned reaction, and so on.

Next there appears (p. 503) a series of explicitly stated postulates: that the remote excitatory tendencies of Ebbinghaus exist; that remote excitatory tendencies of Ebbinghaus possess the same behavior characteristics as do the trace conditioned reflexes of Pavlov (Lepley's hypothesis); that the period of delay of trace conditioned reflexes possesses an

inhibition of delay; that inhibitions are additive; that caffeine retards the accumulation of inhibition; that inhibitions diminish more rapidly with the lapse of time than do related excitatory tendencies, and so on. So much for the first criterion.

There follows (pp. 504 *ff.*) a series of eleven theorems derived by a formal process of reasoning from the preceding postulates and definitions. For the most part each step of the reasoning is explicitly stated and the logical source of each is conscientiously given. In this connection it is to be observed that the deduction or proof of each theorem is a complex multiple-link logical construct involving the joint action of numerous principles or postulates, as contrasted with simple syllogistic reasoning where but two premises are employed. Moreover, it is to be noted that the system is an integrated one not only in that all the theorems are derived from the same postulates, but also in that the later theorems are dependent on the earlier ones in the form of a logical hierarchy, very much as in systems of geometry. In the derivation of these eleven theorems an attempt has thus been made to conform to the second criterion of a satisfactory scientific system.

Let us now proceed to the examination of this theorem hierarchy from the point of view of the third and fourth criteria.

The first four theorems, while logically necessary for the derivation of the later ones, do not themselves permit any direct experimental test. It is believed, however, that all of the others are sufficiently concrete and specific to permit definite experimental confirmation or refutation. Consider, for example, Theorem V. In plain language, this states that *the central portion of a rote series is more difficult to memorize than are the two ends.* This is, of course, a fact long known to experimentalists (21).[5] Theorem VI, which states that

[5] It is to be noted, however, that while the general picture of series difficulty as shown by experiment agrees with the theorem, there is disagreement in detail. The theorem demands that the maximum difficulty appear in the exact center of the series, whereas it actually appears a little posterior to the center. This, of course, reflects an inadequacy in the theory and calls for a revision of postulates. This systematic reconstruction has already gone far enough to correct the difficulty here considered. This

the difficulty of learning syllables increases most rapidly at the ends of the series but the rate of increase is less and less as the point of maximum difficulty is approached, has also long been a laboratory commonplace (**21**). Theorem VII states that *the reaction times of the syllables of a rote series will be shortest at the ends and progressively longer as the middle is approached;* this is a case of a deduction actually made in advance of experiment. Recently, however, the deduction has had experimental confirmation (**24**).

Now, let us look at Theorem VIII. This theorem means that *syllables in the middles of partially learned series are known better a short time after the termination of practice than they are immediately at the conclusion of practice.* It is particularly to be noted that this theorem flies directly in the face of the old and time-honored principle of forgetting; *i.e.*, it demands that performance shall *improve* instead of deteriorate with the passage of time. When this deduction was first performed our logic seemed to be carrying us into a topsy-turvy world, but our postulates presented us with no alternative; scientific theory is concerned with inflexible logic rather than with predictions based on intuitions or wishes. A year or two after the deduction was made, Ward submitted it to critical experimental test and found the theoretical expectation fully and completely substantiated (**24**).

And so we could go on through Theorems IX and X. It will suffice to say that Theorem IX has recently been experimentally verified by Ward (**24**) after the deduction was made, and that Theorem X states a striking law of economy of learning long known to the literature (**18**, 375 *ff.*).

Finally we come to Theorem XI. Stripped of technical verbiage, this theorem means that *the peak of difficulty in the middle of a rote series when learned by massed practice under the influence of caffeine will be lower than when learned by massed practice in the normal condition.* Two or three years after this deduction had been made, the author set up an experiment

may serve as an example of the successive-approximation procedure characteristic of theoretical development in science. The revised construct will be given in connection with a full statement of the system to be contained in a contemplated publication.

especially to test it. When the experiment was completed and the data tabulated, it was found that the deduction was *not* verified—the peak of difficulty in the middle of the series was a little higher under caffeine than in the control series, where the subjects learned the material in a normal condition (10). Here, then, is a case where a definite deduction has been flatly controverted by fact.

Clearly, where a theory is opposed by a fact, the fact has the right of way. In a situation of this kind something is obviously wrong, presumably with one or more of the postulates involved in the deduction. In this particular case suspicion naturally rests most heavily on Postulate VI. At all events, Theorem XI serves to round out and give a further note of realism to this miniature scientific theoretical system. It is a noteworthy event, in the present status of psychological theory, to have a deduction sufficiently anchored by logic to the postulates of the system that a collision with a stubborn experimental fact shall be able to force a revision of the system. It is reasonably safe to assume that the rarity of such collisions at present is not due to the infallibility of current theoretical constructs. Until our systems become sufficiently clear and definite for this kind of event to be of fairly frequent occurrence, we may well suspect that what passes as theory among us is not really making contact with our experimental facts.

A Miniature Scientific Theoretical System by Way of Illustration

Definitions

I. A rote series is a number of nonsense syllables presented visually one at a time for constant periods (*e.g.*, three seconds) with only a fraction of a second between exposures. The subject learns to speak each syllable while its predecessor is still in view, the overt immediate stimulus for each overt reaction being the visual stimulus arising from the preceding syllable.

II. A rote series is said to be learned when the subject can correctly anticipate each successive syllable throughout a single repetition.

III. An 'excitatory tendency,' as emanating from a stimulus, is a tendency for a reaction to take place more certainly and, in case it does occur, to do so more vigorously other things equal, soon after the organism has received said stimulus than at other times.

IV. An 'inhibitory tendency' is one which has the capacity to weaken the action potentiality of a concurrent excitatory tendency.

V. A syllable reaction tendency is said to be spanned by a remote excitatory

tendency and by the parallel inhibition of delay (Postulate III) when said syllable reaction tendency falls between the stimulus syllable and the response syllable associated with the remote excitatory tendency and the parallel inhibition of delay in question.

VI. The 'actual' strength of an excitatory tendency is that strength it would display for action if uncomplicated by concurrent inhibitory tendencies.

VII. The 'effective' strength of an excitatory tendency is that strength it displays in action under whatever conditions of inhibition may exist at the time.

VIII. A remote excitatory tendency is an excitatory influence, initiated by a syllable as a stimulus, exerted upon any other syllable as a reaction with the exception of the syllable immediately following the stimulus syllable.

IX. A trace conditioned reaction is an S → R relationship (acquired in isolation by a special conditioning technique) which has the characteristic that an appreciable interval (*e.g.*, sixteen seconds) may elapse between the presentation of the overt stimulus and the taking place of the overt response.[6]

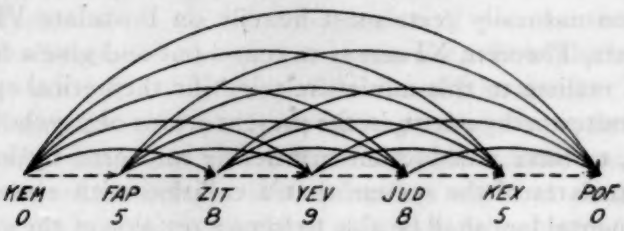

FIG. 1.

Diagrammatic representation of both the immediate and the remote forward excitatory tendencies assumed to be operative in rote series. The straight broken arrows represent immediate excitatory tendencies and the curved solid arrows represent remote excitatory tendencies. The number of remote excitatory tendencies spanning a given syllable, such as ZIT, is given by the formula $(n - 1)(N - n)$ where N is the total number of syllables in the series and n is the ordinal number of the syllable whose span value is under consideration. Thus, in the above example, $N = 7$ and the n for ZIT = 3. Accordingly, $n - 1 = 2$ and $N - n = 4$. Consequently, ZIT should have 2×4 or 8 remote excitatory tendencies spanning it. The truth of this computation may be verified by counting the number of curved lines immediately above the syllable in question. The number of remote excitatory tendencies spanning the several syllables is given beneath each.

[6] What is spoken of as the 'overt' stimulus of a trace conditioned reaction is not regarded as the 'actual' stimulus. The 'overt' stimulus is supposed to set in motion some kind of slowly changing internal sequence more or less characteristic of each such stimulus. It is the stimulus value of the phase of this sequence immediately preceding the reinforcing stimulus which is regarded as the 'actual' stimulus of the trace conditioned reaction. It thus comes about that the stimulus of POF (Fig. 1) is compounded of 6 elements from as many different sources, whereas that of FAP arises from a single source. But, so far as is now known, the ease of conditioning is not influenced by the complexity of the stimulus, so that the 'actual' strength of the excitatory tendencies to the arousal of POF and FAP should be alike so far as this factor is concerned. This means, necessarily, that the *immediate* excitatory tendency from KEX to POF must be appreciably weaker than that from KEM to FAP or even from ZIT to YEV. This last deduction is obviously capable of experimental test.

X. 'Massed practice' is a method of learning in which the series is run through from beginning to end almost continuously, *i.e.*, with a pause only of from ten to twenty seconds between successive repetitions.

XI. 'Distributed practice' is a method of learning in which an appreciable interval of time (*e.g.*, one hour or more) is interposed between successive repetitions; otherwise it is the same as 'massed practice.'

Postulates

I. Rote series possess functionally potent remote excitatory tendencies extending forward from each syllable of the series as an overt stimulus to every syllable placed later in the series as an overt response except the response syllable immediately following the stimulus syllable. (Ebbinghaus, **4**, 106.)

II. The remote excitatory tendencies of Ebbinghaus possess the same characteristics as the trace conditioned reflexes of Pavlov. (Lepley's hypothesis, **12**; **13**.)

III. The period of delay of trace conditioned reflexes possesses a power to inhibit (temporarily) to a certain extent the functional strength of excitatory tendencies, the reactions of which would otherwise tend to take place during such period. (Pavlov, **17**, 173.)

IV. The inhibition of delay of each succeeding degree of remoteness (distance between overt stimulus and overt response) decreases progressively, each additional increment in remoteness diminishing the inhibition, on the average, by a constant amount. (Assumed by rough analogy to corresponding excitatory tendencies, **4**, 106.)

V. Inhibitions of delay operative at the same time summate arithmetically. (Assumed from analogy to excitatory tendencies, **22**, 36 *ff.*)

VI. Inhibitions of delay accumulate to a lesser degree when the subject is under the influence of caffeine than do associated excitatory tendencies. (Evans, **5**, 365.)

VII. When learning is performed by massed practice, the ratio of the actual strength of excitatory tendency to the inhibition of delay is, on the average, constant throughout the learning process, and such as usually to leave a positive effective strength of excitatory tendency. (Assumed as a first approximation.)

VIII. Inhibitory tendencies in the early stages of weakening through the lapse of time diminish more rapidly than do associated excitatory tendencies. (Pavlov, **17**, 99 and 58 *ff.*)

IX. A constant minimal strength of excitatory tendency is necessary to make recall possible even when no concurrent inhibition is present. (Assumed.)

X. The total aggregate actual excitatory tendency exerted on a syllable as a reaction tendency is, on the average, a constant for all syllables in a given list at a given time. (Assumed.)

XI. A constant minimal 'effective' strength is required of any given excitatory tendency for it to pass the threshold of overt reaction. (Assumed.)

XII. Under the conditions of rote learning, each repetition of a rote series adds, on the average, a constant positive increment to the actual strength of each excitatory tendency of the series. (Pillsbury, **18**, 370.)

XIII. The greater the functional or 'effective' strength of the excitatory tendency evoking a reaction, the less, on the average, will be the time elapsing between the stimulus and the reaction. (Simley, **23**.)

XIV. The 'actual' strength of excitatory tendencies accumulated through repetitions is not influenced by the previous presence of superposed inhibitions of delay. (Assumed.)

Theorems

I

If the number of syllables in a rote series is N, and the ordinal number of a particular syllable counting from the beginning is n, the syllable as a reaction tendency will be spanned by $(n-1)(N-n)$ *remote excitatory tendencies.*

1. It is evident (Postulate I and Fig. 1) that a given syllable in a rote series (Definition I) is spanned (Definition V) by remote excitatory tendencies (Definition VIII) all of which originate in the syllables anterior to itself and which terminate in syllables posterior to itself; *i.e.*, each syllable anterior to a given syllable has a remote excitatory tendency extending to each syllable posterior to said syllable n.

2. Since there are $(n-1)$ syllables anterior to a given syllable and $(N-n)$ syllables posterior to it, it follows from (1) and Postulate I that there must be $(n-1)(N-n)$ remote excitatory tendencies spanning any given syllable as a reaction.

II

Within any rote series, the mean degree of remoteness of remote excitatory tendencies spanning a given syllable is the same for all syllables, viz., $\frac{N+1}{2}$.

1. In continuous series the terms of which increase by constant steps, the mean of the series as a whole will be given by the mean of the values appearing at the respective ends of the series.

2. By Postulate I (and Fig. 1), the remote excitatory tendencies spanning a given syllable and originating in a particular syllable, satisfy the conditions of (1).

3. Take any syllable, n, of a rote series. It is evident (Fig. 1 and Postulate I) that those remote excitatory tendencies originating in syllable 1 and which span syllable n must have as their greatest length the distance in intervals from the last syllable of the series to the first syllable of the series, *i.e.*, $N-1$ intervals, and for their shortest value the distance in intervals from syllable 1 to syllable $n+1$, *i.e.*, $n+1-1$, or simply n intervals.

4. From (1), (2), and (3) it follows that the remote excitatory tendencies of the set emanating from syllable 1 have as their mean that of $N-1$ and n, or $\frac{N+n-1}{2}$.

5. It is evident also (Postulate 1 and Fig. 1), that the excitatory tendencies of the set emanating from the second syllable must all be one step less in distance than those emanating from syllable 1, *i.e.*, that their mean value must be $\frac{N+n-1}{2}-1$; that the mean of those emanating from syllable 3 must be $\frac{N+n-1}{2}-2$, and so on, the amount subtracted from the fraction in the case of the mean of the last set being one less than the total number of sets.

6. But by (2) of Theorem I, the number of such sets is $n-1$. It follows from (5) that the value subtracted from the fraction which appears in the formula representing the mean of the last set must be $(n-1)-1$, or $n-2$.

7. From (4), (5), and (6), the final mean of the series must be $\frac{N+n-1}{2}-(n-2)$. But by (5) and (6) the means of the several series constitute a continuous series exhibiting constant step intervals. Therefore, by (1), the mean of these means must be given by the mean of the first and last means of the series.

8. By (5), (6), and (7), the mean extent of the series of means must be

$$\frac{\frac{N+n-1}{2}+\frac{N+n-1}{2}-(n-2)}{2}$$

which becomes

$$\frac{N+n-1+N+n-1-2n+4}{4}.$$

The n's disappear, leaving

$$\frac{2N+2}{4} \quad \text{or} \quad \frac{N+1}{2}.$$

9. But since by assumption n was *any* syllable, it follows from (7) that the mean length of remote excitatory tendencies spanning any syllable is like that of all the others, viz., $\frac{N+1}{2}$.

III

The total inhibition of delay operative at any given syllable position is measured by the number of remote excitatory tendencies spanning that syllable position.

1. By Postulates II and III and Definition IX, the intervals of delay of remote excitatory tendencies are the loci of inhibitions of delay.

2. By Postulate IV, the magnitude of these inhibitions of delay is a decreasing linear function of the degree of remoteness of the excitatory tendency in question.

3. It follows from (1) and (2) and Theorem II that the mean magnitude of inhibition (Definition IV) effective at any given syllable position in the series must be like that of all other syllable positions.

4. But if the mean inhibition of delay at all syllable positions is the same, it follows that the total inhibition at any given syllable position must be strictly proportional to the number of remote excitatory tendencies spanning that syllable position.

5. From (4) and Postulate V the theorem follows.

IV

The number of repetitions required for mastery of any particular syllable of a rote series is $T + R_I$, where T is a constant representing the number of repetitions required to produce learning when no inhibition is present, and R_I is a linear function of the number of spannings, i.e. of $(n-1)(N-n)$.

1. By Postulates IX and XII and Definition II, a finite basic number of repetitions, T, will be required to produce the strength of excitatory tendency (Definition III) necessary to evoke reaction when there is no inhibition present.

2. By Postulate X and Definition VI, T must be a constant throughout any given rote series.

3. By Postulates XI and XII and Definitions IV and VII, there must be added to the threshold constant, T, certain repetitions to overcome any inhibitions present.

4. By Postulates V and XII, the number of repetitions at a given syllable will be a direct linear function of the aggregate inhibition at that syllable.

5. By (4) and Theorem III, the number of repetitions required to override the inhibition at any point within a given series must be a linear function of the value $(n-1)(N-n)$.

6. From (2) and (5) it follows that the number of repetitions required for mastery of a rote series at any given point must be the sum of those required to pass the thres-

hold of recall, T, plus those required to overcome the adverse influence of inhibition, $(n-1)(N-n)$, *i.e.*, it must be $T + R_I$ where the latter is a linear function of $(n-1)(N-n)$.

V

The number of repetitions required for mastery of the individual syllables of a rote series is greater in the central region of the series than at either end, the position of maximum difficulty falling at point $\frac{N+1}{2}$.

1. Since, by Theorem IV, T in the expression $T + R_I$ is a constant, it follows that the variability in the number of repetitions required for the mastery of the several portions of a rote series will be a direct linear function of $(n-1)(N-n)$ only, since R_I is a linear function of $(n-1)(N-n)$.

2. If, now, we substitute in this formula the successive ordinal values at the beginning of any rote series, taking the length of the series at any convenient value such as $N = 9$, we have,

Syllable number (n),	1	2	3	4	5	6	7	8	9
Units of repetition to learn,	0	7	12	15	16	15	12	7	0

3. It may be seen by an inspection of the series of values in (2) that the number of repetitions required for mastery increases continuously from the ends toward the middle of the series, the maximum falling at point 5, which may be expressed by $\frac{N+1}{2}$. Thus we have a concrete demonstration of the truth of the theorem for a particular series.[7]

VI

The rate of increase in the number of repetitions required for mastery in a rote series progressively diminishes as the point of maximal difficulty is approached from either end,

1. Taking any convenient length of series such as one of eight syllables ($N = 8$),

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[7] A deduction of the essential portion of this theorem is yielded by the calculus:

$$R_I = a + m(n-1)(N-n)$$

Expanding we have,

$$R_I = a - m[+n^2 + n(N+1) - N]$$

Differentiating with respect to n,

$$\frac{dR_I}{dn} = m[-2n + (N+1)]$$

at the maximum,

$$\frac{dR_I}{dn} = 0$$

whence

$$-2n + (N+1) = 0$$

and solving for n we have,

$$n = \frac{N+1}{2}$$

therefore, the position of maximum difficulty falls at the point $\frac{N+1}{2}$.

we have by Theorem IV the formula $T + R_I$, remembering that T is constant and R_I is a linear function of $(n - 1)(N - n)$.

Syllable number (n),	1	2	3	4	5	6	7	8
Units of repetition to learn,	0	6	10	12	12	10	6	0

2. Here it may be seen that the units of repetition required for mastery increase by 6 points from syllable 1 to syllable 2, by 4 points from syllable 2 to syllable 3, and by 2 points from syllable 3 to syllable 4; *i.e.*, the rate of increase in difficulty progressively diminishes as the middle is approached.

3. A corresponding inspection reveals the same type of progression from the posterior end of the series as point $\frac{N+1}{2}$ is approached.

4. (1), (2), and (3) constitute a concrete demonstration of the truth of the theorem for a particular series.[8]

VII

The reaction times of the syllables of a rote series learned by massed practice will be shortest at the end positions and progressively longer the farther the syllable from the ends of the series.

1. By Theorem V, syllables require an increasing number of repetitions to learn as the point of maximal difficulty of the series is approached from either end.

2. From (1) and Postulates XI and XII and Definition VII, it follows that the syllables near the ends of the series will rise above the threshold of recall progressively earlier than the syllables farther from the ends.

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[8] A deduction of the essential portion of this theorem is yielded by the calculus (see note to Theorem V):
It follows from

$$\frac{dR_I}{dn} = m[-2n + (N+1)] \text{ (where } m \text{ is positive)}$$

that

$$\frac{d^2R_I}{dn^2} = -2m$$

whence, if

$$n < \frac{N+1}{2}$$

$\frac{dR_I}{dn}$ is positive
$\frac{d^2R_I}{dn^2}$ is negative
} whence, the curve increases toward the right with decreasing slope

if

$$n > \frac{N+1}{2}$$

$\frac{dR_I}{dn}$ is negative
$\frac{d^2R_I}{dn^2}$ si negative
} whence, the curve decreases toward the right with increasing (negative) slope.

3. From (2), Definition I, and Postulate XII, it follows that the syllables near the ends of the series will be overlearned more than those at the middle, *i.e.*, they will have progressively stronger effective excitatory tendencies (Definition VII) as their distance from the middle of the series increases.

4. By (3) and Postulate XIII the theorem follows.

VIII

In rote series learned to a variable but incomplete degree by massed practice, the number of successful reactions in the middle portion of the series will be greater after a certain period of no practice than at once after the conclusion of learning.

1. By Theorems I and III and Postulate VII, it follows that throughout the learning of rote series where the learning is performed by massed practice there will be variable but finite amounts of inhibition operative on the excitatory tendencies of syllables in the interior of series, *i.e.*, upon all but the two end syllables.

2. By Definition IV, this will depress the effective reactive capacity of such excitatory tendencies (Definition VII) below their actual values.

3. But, by Postulate VIII, inhibitions at first diminish more rapidly during the passage of time than do the associated excitatory tendencies.

4. By (3), during a given interval of no practice the inhibitory tendency will decrease by a finite amount.

5. It follows from (2) and (3) and Postulate XIV that in the early stages of a period of no practice following the learning of a rote series, the effective excitatory strengths of the interior syllables as reaction tendencies will be greater by finite amounts than at the conclusion of learning.

6. From (5) it follows that all syllables as reaction tendencies whose excitatory strengths are above the reaction threshold at the conclusion of incomplete learning will remain above after the period of no practice.

7. Since the degree of learning before interruption varies from one series to another (as here assumed), it follows that of those reaction tendencies which are below the threshold of recall some will differ from the threshold by an amount less than the finite amount indicated in (4).

8. From (3) and (7) it follows that certain syllables which are below the threshold of recall at the conclusion of incomplete learning will be above it at the conclusion of an optimal interval early in the period of no practice.

9. The group of effective reaction tendencies above the threshold at the conclusion of learning (6) added to the group which pass the threshold after an optimal interval of no practice (8) will make a sum larger than the former alone, from which the theorem follows.

IX

In just barely learned rote series the reaction time of syllables in the interior of the series will be shorter after an optimal period of no practice than for the corresponding individual syllables at the conclusion of learning by massed practice.

1. By reasoning analogous to that of (1), (2), (3), and (4) of the proof for Theorem VIII, it follows that the effective excitatory strength of just-learned syllables in the middle of rote series will be greater at some point early in the period of no practice than at the conclusion of learning by massed practice (Definition X).

2. By (1) and Postulate XIII, this increased excitatory strength will be accompanied by shortened reaction time, from which the theorem follows.

X

Rote series will be learned with fewer repetitions by distributed practice than by massed practice.

1. By Theorems II, III, and IV, the most difficult syllables to memorize of a rote series are loaded with inhibitions of delay.

2. By Definition XI, the method of distributed practice involves appreciable periods of time between repetitions. By Postulate VIII these time intervals, if not too long, will dissipate the inhibition more rapidly than the associated excitatory tendency. It follows that for a given amount of training the method of distributed practice will yield relatively less accumulated inhibition than by massed practice.

3. From (2) it follows (Postulates XI and XII) that the method of distributed repetitions will bring the most difficult syllable above the threshold of recall with fewer repetitions than will be the case by the method of massed repetitions.

4. But, by Definitions I and III, the number of repetitions required to learn rote series is that required to learn the most difficult single syllable.

5. By (3) and (4), the theorem follows.

XI

The value obtained by dividing the number of repetitions required to bring syllables above the threshold at the ends of rote series, by the number required in the middle of the same series, will be larger when the learning is done under the influence of caffeine than when done in the normal condition, the learning in both cases to be performed by massed practice.

1. By Theorem V, the middles of rote series learned by massed practice require more repetitions for learning than do the ends.

2. From (1) it follows that the number of repetitions per syllable for learning at the ends divided by the number at the middle R_E/R_M will yield a value less than 1.

3. Now, by Postulate VI, inhibitions accumulate to a lesser degree, other things equal, when the learning is performed under the influence of caffeine. It follows from this and Theorems II and III that less inhibition will accumulate in the middle of the series in question when learning is performed under the influence of caffeine.

4. By (3), Definition IV, and Postulate XII, it follows that the middle syllables will be learned with less repetitions under caffeine than in the normal condition, *i.e.*, that R_M will be smaller than normal. Since caffeine has no such influence on syllables not inhibited, R_E will remain the same.

5. But to reduce R_M in the division R_E/R_M will increase the resulting values.

6. From (5) the theorem follows.

Some Problems Connected with the Evaluation of Psychological Theory

The recognized principles of science, then, provide us with a method which seems capable of bringing some kind of order out of the present chaos in theoretical psychology. Moreover, the program appears to be one to which all theorists, however diverse their postulates provided they are not essentially metaphysical or mystical, may subscribe. Indeed, it seems to be so firmly rooted in the traditions and essential logic

of science that all would-be theoretical work will ultimately come to be judged by the scientific public according to this standard, regardless of the views of the theorists themselves. This brings us to the consideration of certain concrete problems which arise when an attempt is made to evaluate the claims of competing theoretical systems.

In the first place, it should be obvious that all mere systems of classification must be rejected. A dictionary may be systematic, but it can hardly be rated as a theoretical system even when the terms are largely of new coinage. Merely to call a bit of learning behavior a case of 'closure' or 'insight' on the one hand, or a case of 'conditioning' or 'trial-and-error' on the other, will not serve. Such systems cannot pass even the first criterion.[9]

Next we must consider the nature of the concepts and postulates which are admissible as the basis for psychological theory. Some psychologists appear to have assumed that only principles incapable of direct observational verification [10] should be admitted as postulates, whereas others may conceivably have assumed that only principles capable of direct observational verification should be admitted. In a similar manner, one group of theorists may insist that the postulates from which psychological systems evolve must be concerned with *parts*, while another group may insist that they must concern *wholes*. One group of theorists may insist that the postulates must come solely from conditioned reflex experiments, whereas to another group such postulates might not be at all acceptable.

[9] It appears to be at this point that most current attempts in the field of psychological theory break down. Their concepts appear not to be of such a nature that significant theorems may be drawn from them by a rigorous logic. A theoretical system without proven theorems is a paradox, to say the least.

[10] The postulates of a system may be susceptible of two types of verification—one indirect and the other direct. Indirect verification occurs when a deduction from a combination of postulates is observationally confirmed. The failure of such a verification throws doubt on the soundness of all of the postulates involved. This particular doubt is removed when appropriate change is made in one or more of these postulates so that deductions from them conform not only to the new observations but to all those phenomena previously deduced and verified. All postulates are susceptible of indirect verification, but some postulates permit direct verification and some do not. Postulates regarding the positions and movements of electrons, for example, permit indirect verification but not direct observation.

From the present point of view this argument is quite footless. Actually, all such groups beg the main question. The question at issue is: Can more theorems which will be confirmed in the laboratory be deduced from postulates which are principles of dynamics, or more from postulates which are principles of mechanics, or more from a combination of both types of postulates; can more sound theorems be deduced from postulated parts, or more from postulated wholes, or more from a combination of the two? These are matters which should properly await the outcome of trial; it is conceivable that numerous distinct sets of postulates may prove more or less successful.

The history of scientific practice so far shows that, in the main, the credentials of scientific postulates have consisted in what the postulates can *do*, rather than in some metaphysical quibble about where they came from. If a set of postulates is really bad it will sooner or later get its user into trouble with experimental results. On the other hand, no matter how bad it looks at first, if a set of postulates consistently yields valid deductions of laboratory results, it *must* be good.[11] In a word, a complete *laissez-faire* policy should obtain in regard to postulates. Let the psychological theorist begin with neurological postulates, or stimulus-response postulates, or structural postulates, or functional postulates, or factor postulates, or organismic postulates, or Gestalt postulates, or sign-Gestalt postulates, or hormonic postulates, or mechanistic postulates, or dynamic postulates, or postulates concerned with the nature of consciousness, or the postulates of dialectical materialism, and no questions should be asked about his beginning save those of consistency and the principle of parsimony.

Third, we must be extremely careful to insure the rigor of our deductions. Perhaps the most common fallacy in current would-be theories is the *non sequitur*—the supposed conclusion simply does not follow from the postulates.

[11] Consider the Riemannian geometry, which insists that the sum of the angles of a triangle is greater than two right angles (19, 58). This is repugnant to common sense, yet Einstein used the Riemannian geometry as the basis for making the greatest single advance in scientific theory since the time of Newton.

In particular we must be on our guard against what might be called the 'anthropomorphic fallacy.' By this is meant a deduction the critical point of which turns out to be an implicit statement which, if made explicit, would be something like, "If I were a rat and were in that situation I would do so and so." Such elements in a deduction make it a travesty because the very problem at issue is whether a system is able to deduce from its postulates alone what a normal man (or rat) would do under particular conditions. It is this fallacy which justifies the inveterate aversion of scientists for anthropomorphism. It is true that as a practical guide to the expectation of what a rat, or an ape, or a child, or another man will actually do in an as yet untried situation such an approach is, of course, of value and should be used. But predictions arrived at in such a way are of no value as scientific theory because a truly scientific theory seeks to deduce what anthropomorphism reaches by intuition or by naïve assumption. Prophecies as to the outcome of untried experiments based merely on such anthropomorphic intuitions should be credited to the intuitional genius of the prophet rather than to the theoretical system to which the prophet may adhere. Predictions, however successful, can have no evidential value as to the credibility of the prophet's system until he is willing and able to exhibit the logic by which his predictions flow from the postulates of that system, and until this logic is really rigorous, until it consists of something more than the feeble *non-sequiturs* too often presented in our literature as scientific explanations.

Summary and Conclusions

Scientific theory in its best sense consists of the strict logical deduction from definite postulates of what should be observed under specified conditions.[12] If the deductions are lacking or are logically invalid, there is no theory; if the deductions involve conditions of observation which are impossible of attainment, the theory is metaphysical rather than scientific; and if the deduced phenomenon is not observed

[12] Truth, for the purposes of the present paper, is to be understood as a theoretical deduction which has been verified by observation.

when the conditions are fulfilled, the theory is false. Classifications of the phenomena of a science may have distinct expository and pedagogical convenience, but convenience cannot be said to be true or false. Points of view in science may possess the virtue of fertility by suggesting new directions of investigations, but neither can fertility be said to be true or false. On the other hand, truly scientific theory, from its very nature, must permit the observational determination of its truth or falsity.

It is believed that upon the above conceptions of scientific theory may be based a robust hope of bringing order out of our present theoretical chaos. It is conceivable, of course, that more than one scientific system may be able to deduce the major phenomena of learning. However, the history of scientific theory has shown that successful duplicate explanations of the same natural phenomena have usually turned out to be at bottom the same. Accordingly, we may expect that when we have put our scientific house in order there will be little more disagreement in the field of theory than in the field of experiment, and presumably such disagreements as appear will prove to be but temporary.

Assuming both the possibility and the desirability of such an outcome, the question arises as to how it can most promptly be achieved. First, it is believed that the thing most urgently needed at the present moment is a clear statement of postulates with accompanying definitions of terms. Second, these postulates should be followed by the step-by-step deduction of the theorems making up the body of the system. No doubt the meticulous presentation of the logic behind the theorems of a system may at first strike certain readers as pedantic. Moreover, it is an unfortunate fact that for persons untrained in a particular system, the more rigorous the logic the more difficult it becomes to comprehend. It is encouraging, however, to note that difficulty of comprehension by the tyro has not prevented the development of mathematical theory in the older sciences, and with them rigor of deduction has not usually been regarded as pedantry. A number of indications point to a considerable development

of this kind of theoretical work in psychology within the immediate future.

As this development proceeds, we may anticipate that those systems or points of view which are unable to satisfy the postulational requirements of truly scientific theory will come to be known for what they are, and will lose adherents. The proponents of other points of view may be expected gradually to clarify their basic postulates and from these to evolve systems of rigorously proved theorems. Of this latter group of systems, presumably, it will be found impossible to apply the experimental check to the theorems of some because the systems in question either do not specify clearly the conditions under which phenomena should occur or else they are not clear as to exactly what phenomena are to be expected. Some systems, on the other hand, will doubtless succeed in making genuine contact with experimental facts. Of these, some will probably present such a high proportion of experimental non-confirmations that the confirmations actually observed may be attributable to mere chance.

Finally, let us hope, there will survive a limited number of systems which show a degree of successes appreciably in excess of what chance would produce. Occasionally, in such cases, a failure of a theorem to agree with experimental observation may be accounted for plausibly on the basis of a known and recognized factor operating in such a way as to over-ride the action represented by the theorem. Unless this can be done, however, the postulates of the system must be revised until they yield theorems agreeing with both the new and the old facts, after which there will be made new deductions which will be checked against new experiments, and so on in recurring cycles. Thus theoretical truth is not absolute, but relative.

It seems likely that as the process of theoretical development goes on the surviving systems will show two fairly distinct types of relationship. First, there will be systems which attempt explanations on different levels such as the perceptual level, the stimulus-response level, the neuro-anatomical level, and the neuro-physiological level. It is conceivable that each

might develop a perfect system on its own level. In that case each lower level should be able to deduce the relevant basic postulates of the system above it in the hierarchy of systems. Here, of course, would be supplementation rather than conflict.

Second, there may be some systems which attempt explanation at the same level. However diverse such systems may appear at the beginning, they may be expected gradually to display an essential identity as they go through successive revisions, the differences at length consisting in nothing but the terms employed. Those systems which concern different but related aspects of learning, by the process of expansion, will finally come to overlap. This overlapping will convert them into approximately the same status as the groups just mentioned, and a gradually approached outcome of substantial agreement may similarly be anticipated. Thus systems may expand by a process of integration.

Finally, sound scientific theory has usually led not only to prediction but to control; abstract principles in the long run have led to concrete application. With powerful deductive instruments at our disposal we should be able to predict the outcome of learning not only under untried laboratory conditions, but under as yet untried conditions of practical education. We should be able not only to predict what rats will do in a maze under as yet untried circumstances, but what a man will do under the complex conditions of everyday life. In short, the attainment of a genuinely scientific theory of mammalian behavior offers the promise of development in the understanding and control of human conduct in its immensely varied aspects which will be comparable to the control already achieved over inanimate nature, and of which the modern world is in such dire need.

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THE OPERATIONAL DEFINITION OF PSYCHOLOGICAL CONCEPTS

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The principles of operationism provide a procedure by which the concepts of psychology can be cast in rigorous form. This procedure consists in referring each concept for its definition to the concrete operations by which the concept is arrived at, and in rejecting all notions founded upon impossible operations. Operational doctrine makes explicit recognition of the fact that a concept, or proposition, has empirical meaning only if it stands for definite, concrete operations capable of execution by normal human beings. It is clear that the examination of psychology's conceptual heritage under the search-light of operationism needs to be undertaken seriously if we are to be rid of the hazy ambiguities which result in ceaseless argument and dissension. The principles which must guide such an examination have been set forth in a previous paper.[2] Briefly, they are:

1. Science is knowledge agreed upon by members of society. Only those constructs based upon operations which are public and repeatable are admitted to the body of science.

2. Psychology regards all observations, including those which a psychologist makes upon himself, as made upon 'the other one' and thereby makes explicit the distinction between the experimenter and the thing observed.

3. Although a particular experimenter may himself become the object of study by another experimenter, at some stage of such a regress an independent experimenter *must* be assumed.

4. A term or proposition has meaning (denotes something)

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[2] S. S. Stevens, The operational basis of psychology, *Amer. J. Psychol.*, 1935, 47, 323–330.

if, and only if, the criteria of its applicability or truth consist of concrete operations which can be performed.

5. Discrimination or differential response is the fundamental operation. It is prerequisite even to the operation of denoting or 'pointing to.'

6. By discrimination we mean the concrete differential reactions of the living organism to environmental states, either internal or external. Discrimination is, therefore, a 'physical' process, or series of natural events, and all knowledge is obtained, conveyed and verified by means of this process.

The result of the operational definition of any particular concept cannot be foreseen until the examination has been made. Some concepts may have to be discarded as devoid of operational meaning, and others may have to be revised to accord more fully with empirical fact. Numerous concepts, however, turn out to be already operationally founded.

I. Existence and Definition

Few concepts have proved as troublesome to psychology as the concept of *existence*, and yet this concept is fundamental to the notion of definition itself. We might have avoided this embarrassment if we had recognized that *existence* is used in two senses: (1) to denote the presence, as opposed to the absence, of a certain object or event, and (2) to affirm the adequacy of a definition. The first usage is both legitimate and univocal, for in that sense *existence* is determined by certain positive and concrete operations about which there is generally universal agreement. Men, for example, with similar capacities for discrimination do not dispute the existence of the earth under their feet when by *existence* it is meant that the earth provides a basis for certain simple differential responses. But sometimes there is agreement as to the presence of such responses and yet disagreement as to the existence of something which can be determined only by those responses. Thus controversy has flourished about a host of problems such as the *existence* of mind in animals,

consciousness in man, emotion in cats, instincts in infants, and space perception in the blind. Now, if we agree as to the facts, we can only argue about definitions. If psychologists agree as to what acts an infant performs in the course of its maturation—and they do in general—then it is only a matter of convention and definition whether or not the acts are called instinctive. The choice of names for things is, of course, a matter of great practical importance, but operationism insists that there is no magic to it. The existence or non-existence of objects and events is an affair of discrimination; their classification and naming depend upon the conventional use of language; and in no case need an argument about *language* cast doubt upon *existence.*

The complexities of psychology and the constant discovery of new facts make the rigorous definition of certain types of concepts troublesome and elusive. Properly, a definition is the sum total of the criteria (operations) by by which we determine the applicability of a term in any particular instance. These criteria are nothing more than social conventions which take into account the state of factual knowledge at a given time. It is for this reason that the discovery of new related fact may make a revision of the criteria necessary so that we may include or exclude the new observation from the class denoted by the original definition. An instructive example is the effect on the concept of *hydrogen* of the discovery of atoms of atomic weight 2.013. If the concept *hydrogen* is to include atoms of this sort, the definition must be revised to that end, for hydrogen has always been defined as consisting of atoms of atomic weight 1.008. It is a matter of convention whether the definition of hydrogen is revised or whether atoms of weight 2.013 are given a new name and classed as a new element.

No concept can ever be allowed to congeal; operational procedure insures against fixation. Sometimes concepts fill out a term of useful existence and die a natural death (like *imageless thought*) or are executed by a deliberate revision of the language-structure (like *sensory clearness*). Such an event does not mean that the operational basis of the original

concept has been rejected, but only that the basis has been added to and the concept renamed.

The once useful concept *animal spirits* which performed a function that we now attribute to neurones is an interesting case. To the extent that animal spirits was a name used to denote a certain class of observations, such as the tendency for responses to follow upon the stimulation of sense-organs and the observation that sense-organs are connected to the brain by little 'tubes,' the notion was operationally founded. However, the concept did not stop where concrete operations left off, but was charged with fantasies of the sort that animal spirits were gaseous in nature and were derived from the blood by the process of distillation, that they acted and were acted upon by the pineal body, and that their excessive agitation gave rise to the emotions. None of these ideas stood for verifiable operations. They were no more than assemblages of words devoid of empirical meaning. Now, when, in the development of neurology, operations were devised for demonstrating the way in which disturbances at sense-organs are able to affect other regions of the body, scientists were faced with the alternative of redefining the term animal spirits in keeping with the new discoveries or of rejecting the term entirely. They chose to reject it, and so we no longer speak of animal spirits but of action currents.

In general, the more careful we are to define our concepts in terms of those things whose *existence* can be verified by concrete operations, the less likely is it that we shall ever have to discard a concept completely. Operational definition provides for a progressive evolution rather than a *volte-face*.

II. Experience

One thing which all sciences show in common is an insistence that in the last analysis they are founded upon human *experience*. The simple rule has been: in the case of doubt or controversy, go back to the experience which is the empirical foundation of the matter in question. This principle agrees with Bridgman's [3] thought that in defining a concept

[3] P. W. Bridgman, A physicist's second reaction to Mengenlehre, *Scripta Math.* 1934, 2, 3–29.

we go back and back "until presently we are confronted with operations which we must accept as unanalyzable and apprehendable only intuitively by personal experience." *Experience* as used here is apparently identical with that of which William James[4] said, "It is the summum genus of which everything must have been a part before we can speak of it at all." However axiomatic it may seem for us to say that all science is founded upon experience, the notion is suspect from the rigorous point of view of operationism, unless we can establish a satisfactory operational definition of experience. Only such a definition can rescue the term from metaphysics.

Despite the absence of explicit definitions of experience, perhaps we can discover what the physicist, for example, is intending to denote when he uses the term. Bridgman says that for Einstein an ultimate, unanalyzable experience would be the operation of observing 'coincidencies.' What can this statement mean other than that Einstein, himself a 'physical' system, makes certain concrete differential reactions in the face of certain external situations? The ultimate operation in this case is a discrimination. Moreover, it is 'ultimate' only in the sense that it is a relatively simple discriminatory response and one on which almost all men *agree* (perform alike). Similarly, in reducing any other concept of physics to the fundamental operations upon which it rests, we end up with discriminatory reactions about which there is practically universal agreement. The *experience*, then, upon which physical science is founded would seem to be nothing more than a term which, implicitly at least, denotes the sum total of the discriminatory reactions performed by human beings, for *to experience* is, for the purpose of science, *to react discriminatively*.

That we should have to supply experience with such an operational definition was to be expected in view of the principles of operationism we have already laid down. Experience that belongs to human beings must denote some 'objective'

[4] W. James in J. M. Baldwin's 'Dictionary of Philosophy and Psychology,' 1901, 1, article on 'Experience.'

performance on the part of human beings, because such beings are organisms about which we can know nothing except what is manifest in a public, overt fashion. Only the reported part of 'experience' can ever get into science; the rest is meaningless since we have no operations for dealing with it. Moreover, the reported part manifests itself as some form of reaction, and gets into science because it is verifiable, repeatable, and consequently agreed upon by other scientists. Thus it satisfies the criteria of 'objectivity.'

If the 'experience' of the scientist means only his discriminatory responses, what about the 'experience' of the philosopher—is it any different? What is the philosopher's matrix of experience which consists of present data considered in their raw immediacy before thought has analyzed them into constructs, and out of which all knowledge is drawn? This epistemological horn-of-plenty appears in numerous guises. It is the given, the qualia, phenomena, immediate awareness, and the direct experience. Different superstructures of words and notions have been erected around each of these terms, but when stripped of their metaphysical trappings they are all supposed to stand for a 'summum genus' which we cannot get at, but which must be there!

Here again a scrutiny of the specific examples which are given to illustrate what is meant by these varieties of experience shows that in every case an appeal has been made to some type of discriminatory response. It could not well be otherwise, for, if we agree that operations must be public, we exclude from consideration any uniqueness of our own private experience. What other observers cannot verify is not knowledge. Consequently, we can deal with the inner life only as it appears in the operations of report, verbal or otherwise. When, for example, it is said that phenomenologically the contemplation of four dots arranged in a certain fashion on a piece of paper gives rise to the 'immediate awareness' or the 'direct experience' or the 'raw feel' of squareness, the speaker means only that a human organism, when 'tuned' to the proper attitude and shown the dots, makes a characteristic reaction.

The conclusion, then, relative to the existence of experience, an *ultimate matrix* from which all knowledge springs, is negative. The belief in an ultimate matrix is futile anyway, for, if we take a large view we see that nature is an infinite system into which we plunge *in medias res*. We can only 'examine' (react to) the system at some particular time and place and then try to order our reactions into a scheme which we call *science*. Consequently, when we try to go back to experience, as positivists have sought to do, we never reach a last and final *given* out of which constructs are generated.

Moreover, the simplest phenomenological observation is really a complex response of an organism with a long history, and is therefore itself a construct. That is to say, even the most elementary experience, such as seeing a color and recognizing it (naming it, let us say), is conditioned upon the subject's previous history and present attitude, and therefore exhibits the 'inferential' character that is essential to constructs. We can say nothing about organisms without histories—they do not exist. Furthermore, since we can do nothing about unreported experience, and since any reported experience with which we deal is a construct, we are forced to conclude that there is no sense to a statement that experience is a "summum genus of which everything must have been a part" before it was a construct. There are *only* constructs,[5] first, last, and always.

III. Attributes of Sensation

The *sensation* was formerly defined as the unit or element of experience, but, since that definition was never made explicitly operational, the attacks of the Gestalt school have readily been effective in impugning it. The term *sensation* is still widely used, however, and in such a way as to lend

[5] The distinction made by M. Margenau (*Philos. Sci.*, 1935, 2, 48–72) between *data* and *constructs* and by H. Feigl (*Philos. Sci.*, 1934, 1, 420–445) between the *language of data* and the *language of constructs* is out of order in operationism. A datum *is* a construct. Those who distinguish between them appear to do so on the basis of simplicity: the more elementary discriminations are called data, and the more complex ones are called constructs. There can, of course, be no objection to a distinction between simple constructs (of low order) and complex ones (of high order).

itself to operational treatment, through an examination of the criteria which determine the word's applicability in any particular instance.

Since sensation cannot refer to any private or inner aspect of consciousness which does not show itself in an overt manner, it must exhibit itself to an experimenter as a differential reaction on the part of an organism. Additional criteria for it are that it shall show a correlation with stimulation of some sense-organ and vary concomitantly with changes in the stimulus. Its distinction from *perception* is conventional and arbitrary.

What is important here is that from the point of view of science we never find *red* as such; we find only such situations as *man sees red*, *i.e.*, an organism discriminates. Thus the *sensation red* is a term used to denote an 'objective' *process* or event which is public and which is observable by any competent investigator. The relation remains true even when the same individual serves both as experimenter and as 'organism,' for his role as experimenter could be taken over by another person without affecting the result.

In the same way that *sensation* denotes a class of reactions which satisfy certain criteria, *attribute* of sensation denotes a sub-class which satisfies more restricted criteria. We find operationally that when we present a given stimulus to an observer we may get a discriminatory reaction in terms of any one of several aspects of the stimulus, depending upon the attitude of the observer. Therefore, we apply a different name to each of these several classes of reactions.

The specification of the attributes of sensation in a given sensory modality and the establishment of adequate criteria for them are contigent upon experimental discoveries. Thus, in the case of audition, the classical criteria of inseparability and independent variability must be modified now that the manner of the dependence of the attributes upon the dimensions of the stimulus has been discovered,[6] for the relationship

[6] S. S. Stevens, The attributes of tones, *Proc. Nat. Acad. Sci.*, 1934, **20**, 457–459, S. S. Stevens, The relation of pitch to intensity, *J. Acoust. Soc. Amer.*, 1935, **6**. 150–154.

turns out to be such that no single attribute can be varied independently while all others remain constant. However, it is possible to hold one attribute constant and vary all the others. By this procedure four aspects of tone, pitch, loudness, volume, and density,[7] have been determined as satisfying the criteria of a tonal attribute. These criteria are:

1. A tonal attribute is a response elicited from a normal observer. (There is no sharp division here; conventional standards must be accepted.)

2. It is obtained with pure tones. All of the complex nuances due to impure tones defy systematic treatment and classification, at least at present.

3. It shows continuous variation when one or both of the dimensions of the stimulus is varied. (The criteria of continuity in this case are the ones usual in physics, although we have reason to believe that sensation is basically quantal. Thus loudness is a continuous function of intensity in the same sense that plate current is a continuous function of grid potential even though the charge of the electron is discrete and finite.)

4. Every attribute is a different function of the two dimensions of the stimulus, frequency and energy. Every attribute can be held constant, therefore, in the face of variation of the other attributes.

The old notion of the *inseparability* of the sensation and its attribute is precisely equivalent to the statement that an attribute is a particular discriminatory reaction belonging to the class of discriminatory reactions known as sensations. *Inseparability* is implied by what we have already said.

The class of reactions which we call *attributes* is obtained from organisms which have been 'set' or 'tuned' so that they respond to a certain aspect of the stimulus-process. This tuning of the observer is one of the fundamental operations underlying the concept of attribute. The ability of the experimenter to set the observer, for example, to respond to loudness and not to pitch is crucial to the determination of the attribute *loudness*.

[7] S. S. Stevens, Tonal density, *J. Exper. Psychol.*, 1934, 17, 585–591.

It is, moreover, crucial to the discovery of any new attributes. For that reason, let us examine the case of the discovery of a new attribute, tonal density.

IV. Tonal Density

Tonal density was discovered first as an attribute because observers in an experiment on tonal volume occasionally gave responses (verbal descriptions) which were different from their responses for pitch, loudness or volume. These observers, when asked to equate two tones with respect to this new aspect, did so in a consistent and unique manner, characteristic of none of the other known attributes. Up to this point everything is clear. We have a straight-forward definition of density: *density* is a term denoting the fact that these observers, under a certain attitude, made certain discriminations. (The word *density* was chosen because the observers agreed that it was the best existing word to designate the experience they had from the tones.) But next the problem arose as to what operations would be required to show that the concept of tonal density could be extended to a naïve observer. First of all we could merely ask him to notice the density of a tone. If his past experience had been of the right sort, it might happen that this instruction would be sufficient to 'tune' him to the proper attitude. (In practice this usually turns out to be the case.) Suppose, however, he had had no experience with the word *density* in any of its usages, then we might have to dispense with language and resort to a round-about procedure which may be called the method of *successive approximation.* It is this method that we should use in the case of animals. We should keep the subjects at work by various motivating devices and reward them only when they achieve the reaction for which we are looking. This method is the last resort in the operation of 'tuning' the subject.

In general, the procedure is as follows: We note that organisms make differential responses to stimuli and we call these differentiations by such names as *pitch, density, saturation, hue, extent, etc.* Then we find that we want another

organism to make similar differentiations, so we proceed to persuade it, by words or by a system of reward and punishment, to react until it performs the differentiation which we seek. When it does, we conclude that it has achieved the proper 'set,' for the operational test of the subject's attitude *is* the particular class of response he gives, and the mode of variation of that response as a function of the stimulus.

V. Conclusion

The foregoing discussion has dealt with certain representative concepts—existence, experience, sensation and attribute—in an effort to cut them to the operational pattern and thereby rid them of all metaphysical excess. The ultimate success of such efforts depends upon the diligence with which the concepts are kept under observation so that they may be constantly revised to accord with new discoveries or to adjust to new demands of simplicity and utility. No concept can be defined once and for all: every concept of science requires constant purging to keep it operationally healthy.

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THE STRUCTURE OF THE VISUAL WORLD
II. THE ACTION OF MOTOR IMPULSES ON SENSORY EXCITATIONS

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1. Introductory Remarks

The preceding paper of this series (5) set forth the outlines of a 'dynamic' theory regarding the basis of visual perception. According to this theory, phenomenal objects are not mere 'copies' of sensory excitation-patterns; perception is based upon action-patterns, or sensorimotor coordinations. The fruitfulness of this conception was suggested by applying it to two problems: the problem of the localization of visual impressions, and that of the perception of visual wholes or unities.

The present paper will suggest that motor processes are concerned in perception in still another way. Not only do motor impulses directly determine the character of visual consciousness, but they can also influence perception in an indirect way, at the purely physiological level.

The physiological process of perception begins with a stimulus-pattern, which gives rise to a pattern of sensory excitations in the brain. This sensory pattern excites a system of oculomotor impulses. Now we proceed to suggest that these motor impulses can in turn *react* upon the sensory pattern which causes them, and, under certain conditions, produce a radical change in the *spatial distribution* of this pattern. That is to say, the sensory and motor excitations form an intercommunicating system, in which the sensory not only control the motor, but the motor can react upon the sensory.

The general idea of such a sensorimotor interaction has already been suggested by W. Köhler and E. Schur (8). In

this paper, however, the arguments advanced in favor of this idea are different from, and, I believe, less hypothetical than those of Köhler and Schur.

The thesis developed here will be carried further in the next paper of this series. I shall there consider a number of visual phenomena which may be grouped together as 'assimilation-effects,' or as effects which exemplify a tendency for visual patterns to change in the direction of homogeneity or simplicity. I shall attempt to show that all these phenomena can be most simply interpreted on the hypothesis of an interacting sensorimotor system. The main purpose of the present essay is to serve as a preliminary to the theory of assimilation-phenomena, by justifying the idea of sensorimotor interaction.

2. Visual Perception in Strabismus: Anomalous Community of Visual Directions

Our first line of evidence is furnished by the study of a perceptual anomaly which has been found in connection with the oculomotor abnormality of strabismus (squint).

In normal visual function, each point of either retina has its 'corresponding point' on the other retina, which is situated in an approximately similar position on the retinal surface. Corresponding points are points of 'identical visual direction' (Hering): stimulation of either one of a pair of such points, or of both at once, gives rise to a visual impression which is subjectively localized in the same direction in space. There are strong reasons for believing that the normal correspondence of the retinas is congenitally determined.

When, as in strabismus, the two eyes are unable to adjust their convergence so as to bring the two retinal images of an object upon corresponding areas, one might expect that the subject would experience a constant diplopia (provided both eyes remained functional). There are, however, many squinters who possess single binocular vision. This comes about through the development of an unusual or 'anomalous' mode of cooperation between the eyes (**2**, **10**).

The squinting eye—or, to speak more exactly, its cerebral

apparatus—develops a new system of 'visual directions.' In this new system, a certain point on the periphery of the retina has the same visual direction as the center of the fovea of the opposite eye; and the visual directions of all other retinal points are changed accordingly. By virtue of this reorganization, the perceptions of the two eyes are brought into agreement with each other, and thus binocular single vision may be achieved. Such an acquired system of binocular cooperation is not, at least usually, a complete functional equivalent of the normal correspondence. Hence it is generally called an 'anomalous community of visual directions' rather than an anomalous correspondence.

Now, the development of an anomalous cooperation between the two eyes appears to involve the establishment of a new relationship between points in the retina and regions in the brain. For it has been found in many cases that when anomalously cooperating retinal areas are stimulated by lights of unlike color, the subject experiences typical phenomena of binocular color-fusion. Thus, *e.g.*, complementary colors mix to produce a gray (**10**, pp. 961, 973). There can hardly be any doubt, therefore, that a genuine physiological fusion takes place; the retinal stimuli in one eye must be transmitting their effects to new or abnormal places in the brain.

It is true that there is rather definite neurological evidence to show that the correlation between the retina and the visual projection-area in the brain is fixed anatomically. However, there is also good reason to believe that the 'psychophysical zone,' or cortical region upon which visual experience directly depends, is located at a higher level than the projection-area. The deviation of visual excitations which we are considering must therefore be located between projection-area and psychophysical zone.

How is this deviation brought about? It occurs in a situation where there is an abnormality of sensorimotor coordination. The tendency of the squinting eye to fixate objects with the fovea, in the normal fashion, has been replaced by a tendency to adjust the eye so that the retinal image falls on an eccentric region. In this way a motor harmony between the two eyes has been accomplished.

Now, let us propose the idea that the perceptual abnormality of the squinter is directly dependent upon the motor abnormality. In other words, the pathway followed by the sensory excitations in the brain is influenced by the conditions in the motor system. As a result of the abnormal motor impulses of one eye, the excitations initiated in that eye are forced to pass to new places in the psychophysical zone.

3. Monocular Diplopia

This interpretation seems to be borne out by the facts of *monocular diplopia*. In certain rare cases, a single image upon one retina gives rise to *two* perceptual images, one localized in normal fashion, the other in anomalous fashion (2, 4). Here we have a curious state of affairs in which the normal correspondence and the anomalous community of directions exist simultaneously.

In such a case it would seem that a single retinal stimulus gives rise to excitement at two different places—a 'normal' and an 'anomalous' place—in the psychophysical zone. This inference is supported by the findings of Bielschowsky (1), in a well-known study of monocular diplopia. This investigator presented to his patient two objects of different color, one beside the other. In the patient's monocular vision each object produced two visual impressions, one 'normally' and the other 'anomalously' localized. By appropriate placement of the objects, the 'normal' impression of one could be brought into apparent coincidence with the 'anomalous' impression of the other. Under these conditions the patient experienced typical phenomena of color-mixture—blue and yellow mixing to produce gray, etc. This result corroborates the evidence from color-mixture experiments which was cited in the previous section.

If anomalous cooperation is to be ascribed to the effect of abnormal motor impulses upon the sensory excitations, then monocular diplopia can be referred to the simultaneous presence of *two* different systems of sensorimotor coordination. Normal motor impulses tend to keep the sensory excitations

in their 'normal' places in the brain-field, while abnormal impulses tend to deviate them towards 'anomalous' places.

This idea is substantiated by the self-observations reported by Professor Tschermak, who is himself a squinter. This writer states that he experiences monocular diplopia under certain special conditions; namely, if he closes, say, the left eye, and endeavors with this closed eye to 'fixate' an object in the field of the right eye, the objects in that field appear double (9). Here we have a clear indication that the doubleness of vision is directly dependent upon a doubleness of fixation-tendencies.

In this connection we may also mention a case of monocular polyopia accompanying hysteria, which has been described by Schilder (6). Schilder found that this perceptual disorder was strictly dependent upon an abnormal state of the oculomotor innervation-mechanism, involving 'a conflict of different eye-movement impulses.' One may reasonably suppose that this case was in principle similar to that of the squinters we have been discussing.

4. The Schumann Phenomenon

According to some interesting experiments recently reported by Schumann (7), phenomena of monocular diplopia can be aroused in normal subjects under appropriate conditions. Schumann's subjects projected a foveal after-image upon a homogeneous field, and, while continually maintaining central fixation, concentrated their attention vigorously upon a peripheral place in the field. As a result, *the after-image was seen in two different places simultaneously*—in the center and at the place on which attention was directed.

In the case of Schumann's subjects, one assumes, the experiment succeeded only with after-images and not with real objects. However, in the case of an abnormal subject whom I have recently studied, the same effect could be elicited with real objects. This subject, C., manifests a number of visual peculiarities, some of which will be discussed at length in our next paper. In the present connection the following fact is of particular interest. In experiments on

peripheral vision it was found that C. possesses a remarkable ability to maintain steady fixation upon a central object and at the same time attend to an eccentric object. It is as if the conflict of motor impulses, which normally produces a strong tendency towards fluctuation of the gaze, were much weaker in his case than in that of the normal person. If the success of the Schumann experiment with real objects demands an extremely steady fixation despite the division of attention, we can understand why C. obtains the effect where the normal subject can not.

If C. with monocular vision steadily fixates a small figure upon a uniform background, and meanwhile concentrates for a few seconds upon a nearby region of the background, a second impression of the figure appears in this peripheral place. C. maintains that this accessory impression is fully as vivid as the original, and is far more vivid than any mental image which he can evoke. (He does not possess eidetic imagery.)

Secondary images are more easily elicited in the horizontal than in the vertical direction. After a secondary image has appeared, C. has difficulty in 'holding it in place'; it spontaneously tends to move towards the center and coincide with the first impression.[1]

5. On the Theory of the Schumann Phenomenon

From the results of his after-image experiments described above (in conjunction with those of some other experiments), Schumann arrives at the conclusion that there is a general tendency for the phenomenal positions of all objects in the visual field to change with shifts in the direction of attention. This change obeys the following rule: The impressions of the fovea appear at the place where attention is directed, and all the other impressions in the field change their apparent locations correspondingly.

Schumann suggests that attention controls the actual

[1] It may be remarked that these experiments were originally performed not as a test for the Schumann phenomenon but with a quite different purpose; the result was equally unanticipated by both subject and experimenter.

distribution of sensory processes in the brain. With each change in the direction of attention, there is a readjustment of the system of lines of flow between retina and psychophysical zone.[2] Where attention is divided between two different spots in the field, as in the after-image experiments, the lines of flow divide and pass to two different places in the psychophysical zone.

Now, the concentration of attention upon a particular place in the visual field involves the arousal of oculomotor impulses which strive to direct the fovea upon that place. We may suggest, therefore, that the proximate cause of the displacement of excitations is to be sought in these *motor impulses*. If this assumption is right, then Schumann's principle may be formulated in the following way: Fixation-impulses tend to shift the pattern of sensory excitations in such a way that the foveal impressions are seen at the place in the visual field towards which the fovea is impelled to orient itself.

Schumann mentions the possibility of applying his hypothesis to the explanation of the phenomena of monocular diplopia in strabismus. It would appear that our reformulation of this hypothesis, in terms of fixation-impulses rather than in terms of attention as such, offers a better basis for understanding the anomalous perceptions of squinters.

6. The Influence of 'Tonus' upon the Distinctness of Vision (Goldstein and Jablonski)

There is evidence to suggest that motor processes can not only influence the localization of sensory excitations in the brain, but that they can also determine whether or not the sensory processes shall be sharply *localized* at all. That is to say, it is apparently possible for motor processes to exert a direct influence upon the actual *distinctness of vision*. This indication is given by a recent study of Goldstein and Jablon-

[2] Schumann applies this principle to explain the fact that the apparent positions of objects remain constant despite movement of the eyes. According to his interpretation, the displacement of the retinal image is exactly compensated by the change in cerebral location produced by the shift of attention which precedes eye-movement.

ski (3) which deals with the visual anomalies accompanying a disorder of 'tonus.'[3]

Goldstein and Jablonski's patient had a strong motor 'deviation-tendency,'[3] and, like many other such patients, she experienced vertigo except when she held her head in a 'preferred position,' with a lateral inclination. With the head in the preferred position, the patient had good visual acuity. If, however, she was required to hold her head straight, an abnormal 'fusion-tendency' displayed itself, and the field became extraordinarily blurred. Her very poor visual acuity under this condition was evidently correlated with a change in the distribution of tonic innervations. The reduction of acuity was partly due to the fact that the general modification of tonus affected the tension of the ciliary muscle, causing a temporary myopia. However, the fusion-tendency still remained very pronounced even when this myopia had been corrected by lenses.

It would seem, therefore, that the disturbance of tonus must have exerted a direct influence upon the distribution of central sensory processes. If this inference is correct, our hypothesis of sensorimotor interaction is substantiated from still a new point of view.

7. Summary

1. This paper advances the hypothesis that the sensory and motor processes of vision form an intercommunicating system, in which the sensory not only control the motor, but the motor can react upon the sensory.

2. Facts pointing towards such an inference are found in certain anomalies of strabismic vision (anomalous community of visual directions; monocular diplopia). These facts suggest that an abnormality of sensorimotor coordination may result in an actual displacement of sensory excitations in the brain.

3. Schumann, working with normal subjects, found that the concentration of attention upon a place in the peripheral field may cause a foveal after-image to appear double. (An abnormal case is described here, in which the same effect

[3] *Cf.* the foregoing paper of this series (5).

was obtained with real objects.) The Schumann phenomenon may be another example of the influence of motor processes upon sensory.

4. The work of Goldstein and Jablonski suggests furthermore that a motor disturbance can directly affect the distinctness of vision. It would appear that motor processes can not only influence the localization of sensory excitations in the brain, but that they can also determine whether or not the sensory processes shall be sharply localized at all.

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THE PRESENT STATUS OF SOCIAL PSYCHOLOGY IN AMERICA

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From time to time it is well that we pause in our study of specific problems and attempt to achieve a synoptic view of things psychological. When American social psychology is approached in this way one discovers that it at present possesses a number of outstanding characteristics, perhaps the most noticeable of which is the wide range of phenomena that are considered as falling within its scope. Thus, for example, the *Journal of Social Psychology* during 1934 published articles with such diverse titles as these:

A Quantitative Comparison of the Nationality Preferences of Two Groups,
Examinations in Familiar and Unfamiliar Surroundings,
Voluntary Simulation of Allergic Sneezing,
The Instability of Post-War Marriages,
An Analysis of the Perception of Intelligence in the Face,
Denunciation and Religious Certainty,
A Psychoneurotic Inventory of Penitentiary Inmates,
Suggestibility in Chimpanzee,
Ghosts of the Sophisticated.

Again, books bearing the title 'Social Psychology' which have been published in America during approximately the last decade contain chapters with such diverse captions as these:

Psychology of Progress (14),
Occupational Groups (3),
Anticipatory Habit Systems (19),
Pathological Forms of Consciousness (2),
The Mechanism of Institutional Development (10),
The Advance to the Higher Plane of Social Conduct (13),
The Physiological Basis of Human Behavior (1),

Patriotism, Nationalism, and Internationalism (6),
Religious Organization (5).
Surely there is here an unusually broad field of endeavor.

Another outstanding characteristic of social psychology in America is the differences existing among various writers concerning the nature of social-psychological problems.[1] Table I gives the approximate percentage of material which various authors devote to representative topics listed in the subject indices of a number of recent books on social psychology.[2] Although these data are not, and by the nature of the case cannot be, absolutely precise, it is evident (1) that writers on social psychology differ enormously in their judgment as to the relative importance of various problems, and (2) that the problems considered as social-psychological by some writers are as different from those so considered by other writers as the problems of one science (such as physics) differ from those of another science (such as chemistry). Of course it is not to be expected that all of the workers in a field of science will agree as to the relative importance of each problem in that field. Neither is it likely that all writers in a given science will discuss exactly the same problems, and perhaps it is not desirable that they should. That the differences should be so great as those indicated in Table I is, however, clear evidence that 'social psychology,' like a political catchword, is all things to all men. The social psychologies written by such outstanding men as Bogardus (3), Allport (1), McDougall (13), Young (19), Kantor (10), and Dunlap (5) are so unlike one another that it would be entirely possible for a reader to understand any one of these

[1] This characteristic is not unrelated to the one previously mentioned. However, whereas we were there concerned with showing something of the range and variety of the problems of social psychology taken by and large, we are here interested in showing something of the range and variety of points of view with reference to the social-psychological character of a number of representative problems taken separately.

[2] Table I can of course be criticised in various ways. Thus, for example, it is true that the selection of topics is arbitrary and that differences in terminology from writer to writer influence the results to some extent. It is also true, however, that these differences in terminology are themselves symptoms of the confusion of tongues that is characteristic of the field as a whole.

TABLE I

APPROXIMATE PERCENTAGE OF THE MATERIAL IN RECENT BOOKS ON SOCIAL PSYCHOLOGY WHICH IS DEVOTED TO REPRESENTATIVE TOPICS LISTED IN THEIR SUBJECT INDICES

	Allport (1)	Bernard (2)	Bogardus (3)	Brown (4)	Dunlap (5)	Ewer (6)	Folsom (7)	Gault (8)	Kantor (10)	Krueger and Reckless (12)	McDougall (13)	Mukerjee and Sen-Gupta (14)	Myerson (18)	Young (19)	Av. of all
Attitude(s)	2	3	5	4		x	6			19				3	3
Audience(s)	1			x		x	x	x						1	x
Censorship		x				1								3	x
Character	1	1	x	3							1				x
Crowd(s)	7	1	3	1	2	2	1	5	1	3		14	1	5	3
Custom(s)	x	1	3	x		2				1			1		1
Emotion(s)	3	1	x	4	4		4				2		1	4	2
Family	4			8	11				x	x	1	1	5	2	2
Fashion(s)	x	1	3	x		1	x	1					x	3	1
Gesture(s)	1		1	x						1			1	1	x
Habit(s)	2	3	2		1	x	x			x	1	1	2	8	2
Imitation(s)	1		1	2	1	3	1				1	1	1	1	1
Instinct(s)	1	4	x	1	1	7	1	6	x	4	22	1	1	1	4
Intelligence	1	3	x		2	x	1	5	x	2			4	1	1
Introv.-Extrav.	1		x	x		x	2			x				1	x
Inferiority	2	x	1			x				x				1	x
Language(s)	7	2		3	3	1	1		x	5		x	5	5	2
Laughter	1		2			1								1	x
Leadership	1	3	2		1	5	1	3		x		2		5	2
Marriage					18		x						1		1
Morale			2			1	x	3		x					x
Nervous system	2			1			2						6	1	1
Prejudice(s)		x	x						x					7	1
Propaganda		x	1		5	1	1		x				x	3	1
Public opinion	1	1	3			1	2	1	x		1	x		9	1
Reflex(es)	4	1		1			x	1		1			x	1	1
Religion	1	x	1		13	2			1	1	2	x		3	2
Rivalry	1	x					2								x
Sublimation	x	x					x			1		1		x	x
Suggestion	2	3	4	1	2	1	1			1	1	x	x	x	2
Sympathy	2	1	x	2		1	x	11			2		1	1	1
Temperament(s)	1	1		1		x	1			2	1	x			1
No. of pages of text material	430	589	434	640	257	407	663	303	416	437	513	289	625	673	

x: greater than 0, but less than 0.5.

volumes quite thoroughly and yet be painfully ignorant of much (or even of almost all) of the content of the others.

Perhaps the basic explanation of the foregoing characteristics is to be found in the existence of great differences of opinion as to the subject matter and the methodology of scientific social psychology, differences so great and so

systematic as to indicate that we are here dealing with what are often known as 'schools of thought.' Although there is no exact counterpart in social psychology for such works in general psychology as 'Psychologies of 1925' (15), 'Psychologies of 1930' (16), and 'Seven Psychologies' (9), the existence of social-psychological 'schools' is indicated by the following list of 'outstanding conceptions of social psychology' as discussed by Kantor (10, Chapter II):

Social psychology as the study of mob or crowd phenomena,
Social behavior as responses to persons,
Social psychology as the study of behavior in groups,
Social psychology as the study of socialization,
Social psychology as the study of mental origins and psychic causes,
Social psychology as the study of ethnic phenomena,
Social psychology as the study of collectivistic mentality,
Social psychology as the study of social forces,
Social psychology as the physiology of complex behavior.

Under the impact of other 'schools' each 'school' has been forced to modify its tenets, and its younger adherents, with the passage of time (and of Ph.D. examinations), have usually tended toward a somewhat more eclectic point of view. The influence of the 'schools' is still apparent, however, and social psychology without 'schools' is as yet a dream rather than a reality.[3]

Another outstanding characteristic of contemporary American social psychology is a distinct tendency toward research on specific, clearly-defined problems which can be investigated by objective methods. As Karpf (11, 428) well says, "We are inevitably on the eve of a period of specialized research and investigation; of the rule of fact, proof, and careful scientific procedure; and of the patient and painstaking cooperation of many in the task of the gradual inductive reconstruction of the field of social-psychological theory."

[3] In general, social psychologists may be said to take a sociological point of view (in which case the emphasis is likely to be on the group) or a psychological point of view (in which case the emphasis is likely to be on the individual). Such distinctions as these, however, are too vague to be really helpful.

With the exception of the volume by Murphy and Murphy (17) and perhaps one or two others, the books now available in the field lag far behind the periodical literature. So far as the writer understands the situation, this is more true of social psychology than of any other field of human knowledge. If history tells us anything, however, it is that a tendency toward the type of research indicated is at once enduring and hopeful.

One disposed to be hypercritical could easily find in contemporary American social psychology a target for many a shaft. Thus, it might be truthfully asserted that it is largely an amorphous mass; that in so far as it is able to formulate any generalizations, they are to be regarded as hypotheses rather than as laws; that the worker in this field, unlike the physical scientist, is never quite sure whether he is studying stones or stars; that there is no more place for 'schools' in social psychology than in astronomy; that there is much metaphysical speculation in this field which is not ordinarily recognized as such; that social-psychological writings are often vague and wordy, and tell us more about the writer than about the subject under consideration; that social psychology needs a Newton to bring about its reorganization and reorientation, revealing relationships to which we are as yet quite blind and giving it a sense of direction; etc. The fact remains, however, that although social psychology may not be entirely clear as to where it is going, it is on its way and this is not so hopeless a situation as may appear to be the case at first sight. Moreover, if one hopes to view this matter in perspective, one must reckon with both the youthfulness of the field and the amazing complexity of its subject matter (howsoever one conceives of it). One human being in comparative isolation is of course vastly more complex than any conceivable combination of chemical 'elements,' but when another human being appears on the scene the psychological problems in the situation immediately become very much greater both in number and in complexity. Indeed, a second individual more than doubles the problems, for in psychology one plus one does not equal two. There is therefore every reason to believe that the weaknesses of social

psychology are far from fatal—they may even prove to be its strength.

Signs of wide-spread interest in social psychology are not wanting. The Year Book of the American Psychological Association for 1935 lists 113 members as teachers of social psychology and 189 members as researchers in this field. And, what is perhaps more important, the periodical literature of social psychology during the last few years has possessed a vigor and freshness that is most encouraging.

Social psychology in America is at present chiefly characterized by (1) the range of phenomena that are considered as falling within its scope, (2) the variety of opinion concerning the nature of its problems that results from the existence of a number of fundamental points of view, and (3) a tendency toward research on specific, clearly-defined problems which can be investigated by objective methods. The changes which this field is undergoing are probably transitional, not transitory, and they are such as to make possible a reasonable belief in unusual, and perhaps startling, developments in the future. The significance of social psychology for both the present and the future is to be found in the fact that we are beginning to realize that it is not man, but our knowledge of man in relation to man, that is 'the measure of all things.'

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FUNDAMENTAL CATEGORIES AS DETERMINERS OF PSYCHOLOGICAL SYSTEMS: AN EXCURSION INTO ANCIENT CHINESE PSYCHOLOGIES

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Each year, when I give a course in the history of psychology, I am impressed with the fact of the direct heritage of our psychology from early Greek thought and that any contribution from Far Eastern thought seems to be entirely absent.

An excursion into primary and secondary sources of early Chinese thought has disclosed a complicated and fairly rigid psychological system of great antiquity which compares very favorably with that of the early Greeks. In many respects the two psychological analyses are similar. This is especially true in two aspects: (1) each is based upon an accepted system of cosmological elements and (2) the psychological analyses, in both cases, are attempted primarily as a basis for ethics and as an explanation of ethical reactions. It is the development of the first of these aspects with which the present paper is concerned.

An apparently very early reference to the elements in the Chinese system is noted by Forke [1] as follows:

> Further on, the Hung-fan in the Shuking (Shû King) informs us of the nature of the Five Elements. The fullest description is to be found in the Shyking. "First the Five Elements: the first is termed water; the second, fire; the third, wood; the fourth, metal; and the fifth, earth. Water is described as soaking and descending; fire as blazing and rising; wood as crooked and straight; metal as yielding and changing; whereas the nature of earth appears for sowing and reaping. That which is soaking and descending becomes salt; that which is blazing and rising becomes bitter; that which is

[1] A. Forke, The world-conception of the Chinese; their astronomical, cosmological and physico-philosophical speculations, London: Probsthain, 1925, p. 230.

crooked and straight becomes sour; that which is yielding and changing becomes acrid; that which is the produce of sowing and reaping becomes sweet."

A. M. Clerke, in the 1929 Edition of the Encyclopaedia Britannica says that the Shuking is "a collection of documents antique in the time of Confucius (550–478 B.C.)" in which are recorded some orders to astronomers by the Emperor Yao who ruled about 2,300 B.C. Forke [2] says, in regard to the antiquity of the Shuking that "This portion of the Shuking must have been written before 2254 B.C., the closing year of Yao's reign. . . ." Hence by the third millenium B.C., the basic categories of the Five Elements were already well established and they remained unchanged throughout ancient Chinese thought and they still are said to remain as the basic conceptions for native Chinese medicine.

By the time of Confucius (K'ung Fu Tse) there had already been a profound organization of thought about these five elements and to each element had been attached a season, a part of the body, a cardinal compass point and a number of psychological processes as well. Forke [3] tabulates these relations as found in the Li-Yün of the Liki (Li Ki) which are the Books of Rites and Ancient Ceremonies and of Institutions. This portion of the Liki is attributed by Legge [4] to Tse Yu, a disciple of Confucius, or to one of his disciples. It will be noted, in this table, that the Five Elements dominate

TABLE I

Elements	Compass Points	Seasons	Intestines	Colors	Sounds [5]	Tastes	Smells
Wood	East	Spring	Spleen	Green	Chio(E)	Sour	Goatish
Fire	South	Summer	Lungs	Red	Chih(G)	Bitter	Burning
Earth	Center	—	Heart	Yellow	Kung(C)	Sweet	Fragrant
Metal	West	Autumn	Liver	White	Shang(D)	Acrid	Rank
Water	North	Winter	Kidneys	Black	Yü(A)	Salt	Rotten

[2] A. Forke, *op. cit.*, p. 4.

[3] A. Forke, *op. cit.*, p. 240.

[4] J. Legge, Chinese classics, Hongkong: Lane, Crawford Co.; London: Trübner, 7 vols., 1861–1872. *Cf.* especially *Liki*, Introduction, p. 4.

[5] Identified as the tone in parenthesis by O. Kinkeldey in the 1929 Encyclopedia Britannica.

the physical, physiological and psychological aspects completely.

Up to this time only four modalities of sensation were recognized—vision, audition, taste and smell—with five fundamental qualities recognized for each. In the case of vision, it is interesting to note that white and black are considered fundamental colors and also that green appears as a chromatic fundamental color along with red and yellow; while blue is not included in the list. The taste list seems very modern with sour, bitter, sweet and salt appearing as fundamental qualities, then, because of the Five Elements, acrid is inserted in the list. The names of the five olfactory qualities can be translated into terms of modern classifications completely, if one identifies the Chinese 'goatish' with the 'Malay bear' of Henning's classification. It is interesting to note that the only place where the five category classification breaks down is in the case of the four seasons. Attention may be called to the similarities in some respects between this table of Chinese classifications on the basis of the Five Elements and the relationship expressed by Hippocrates in Greece (460–370 B.C.) at probably the same approximate period. But in the case of Hippocrates, there were only four traditional elements and hence only four fundamental bodily organs.

Forke [6] quotes the Su-wen, a somewhat later work, which devotes several chapters to the theory of the Five Elements, in which are developed the relationship of the elements and the other qualities along any horizontal row of the table. It is also interesting to note that the Su-wen was written in the style of the Platonic dialogue and consists of questions asked by a fictional Huang Ti of an assistant Ch'i Po. Let us quote two such developments in full:

> Huang Ti asked in what manner cold and heat, dryness and moisture, wind and fire operated on man, and how they produced the transformations of all things. Ch'i Po replied about the operation of these six atmospherical influences in the five quarters. . . . A strict parallelism goes through all his deductions: "The south produces heat; heat produces fire; fire produces bitterness; bitter-

[6] A. Forke, *op. cit.*, pp. 251 *f.*

ness the heart; the heart, blood; and blood the spleen. In heaven it is heat, on earth it is fire, and in the body, the veins. As a breath it respires, and among the viscera, it is the heart. Its nature is hot, its quality effulgence, its manifestation drying up. Its color is red, its transformation luxuriance, its creatures the feathered ones, its government enlightenment, its weather sultry, its sudden change burning, its calamity a conflagration. Its taste is bitter, its sentiment joy. Joy injures the heart, but fear overcomes joy. Heat injures the breath, but cold overcomes heat, and bitterness injures the breath, but salt overcomes bitterness.

The north produces cold, cold produces water, water produces salt, salt the kidneys, the kidneys produce bones and marrow, the marrow produces the liver. In heaven it is cold, on earth it is water, and in the body, the bones. As a breath it is hard, and among the viscera it is the kidneys. Its nature is glacial, its quality is cold and its manifestation . . . (no translation). Its color is black, its transformation frost, its creatures are the shell covered, its government is quiet, its weather . . . (no translation), its sudden change is freezing, its calamity ice and hailstones. Its taste is salt, its sentiment fear. Fear injures the kidneys, but desire overcomes fear. Cold injures the blood, but dryness overcomes cold. Salt injures the blood, but sweetness overcomes salt."

From this account it can be seen that the Su-wen adds some more qualities for each element to those given in the Liki—namely, the five styles of government, the five constituent parts of the body, the five fluids which are really the fundamental properties of each element, and, what is of more importance for psychology, the five impulses. It is interesting to note that here we have at least a suggestion of taste mixture in 'salt overcoming bitterness' and 'sweetness overcoming salt.' Without repeating the parts of the Liki which remain unchanged, such as the colors, sounds, tastes and smells, the remaining facts may be grouped in their relations in the following table:

TABLE II

5 Elements	5 Fluids	5 Parts of Body	5 Intestines	5 Impulses	5 Styles of Government
Wood	Wind	Muscles	Liver(Heart)	Anger	Relaxation
Fire	Heat	Veins(Blood)	Heart(Spleen)	Joy	Enlightenment
Earth	Moisture	Flesh	Spleen(Lungs)	Desire	Carefulness
Metal	Dryness	Skin and Hair	Lungs(Kidneys)	Sorrow	Energy
Water	Cold	Bones(Marrow)	Kidneys(Liver)	Fear	Quietude

It would seem that by this stage in the development of these concepts the identification of the different Intestines with the various Elements had been changed and that they have become more or less uncertain as indicated by the insertion of each organ twice and the offering of a choice of two for each element.

How similar is the identification of the five impulses each with an Element and the quality of that element with the identification by Galen of the four temperaments with the four humors each, in turn, previously identified by Hippocrates with the four elements of Greek cosmology. Galen builds on Hippocrates exactly as the Su-wen builds on the Liki.

Another development, noted by Forke [7] is that Ch'u Yung of the Sung period (A.D. 960–1280) identifies the Five Elements with the five organs of the human body and insists that the *fluids* (humors) correspond to the five intestines. The organs are the ear, the eye, the nose, the mouth and the body serving to produce the five sensations—a list which exactly corresponds to the five modalities of Aristotle.

It is necessary only to list one more classification to complete the picture—that of the Taoist T'an Ch'iao of the 10th Century A.D. which is as follows:

TABLE III

5 Elements	5 Parts of Body	5 Intestines	5 Souls	5 Senses	5 Impulses	5 Virtues
Wood	Muscles	Liver	Mind	Smell	Joy	Benevolence
Fire	Hair	Heart	Spirit	Vision	Gaiety	Propriety
Earth	Flesh	Spleen	Reason	Touch	Desire	Faith
Metal	Bones	Lungs	Animal Soul	Taste	Anger	Justice
Water	Skin	Kidneys	Vitality	Hearing	Sorrow	Wisdom

It will be noted that since the Su-wen, the parts of the body have been changed and that the Five Intestines have again become more definite. Now sensory modalities have

[7] A. Forke, The world-conception of the Chinese, etc., London: Probsthain, 1925, p. 277.

become connected with each element instead of the qualities of each sensation, the relation of the five impulses have been changed and the five virtues have been added.

For a consideration of other ancient psychological aspects beside sensation and impulse or emotion, some interesting facts may be found in the works of Hsüntze (Hsün Tse) dated by Dubs [8] as 320–235 B.C.—a younger contemporary of the perhaps better known Mencius (Meng Tse) 372–289 B.C.

Gleaned from this source [9] we find the following: "The ear, the eye, the nose, the mouth, the body and limbs each receive stimuli and cannot be changed—these are what are meant by the natural (T'ien) senses." Is this statement not essentially the same concept as the 'specific nerve energy', of Johannes Müller many centuries later?

The account then goes on: "The heart is established in the central cavity to control the five senses—this is what is meant by the natural (T'ien) ruler." Is this the germ of the same idea, discussed by Aristotle as the 'common sense', although not developed by the Chinese thinkers as fully as by the Greek?

It is also interesting to note that Hsüntze [10] is definite about insisting upon the use of the empirical method and rationalistic explanation and the avoidance of superstition. Might not the following have been written by Aristotle?

> If people pray for rain and get rain, why is that? I answer there is no reason for it. If people do not pray for rain, it will nevertheless rain. When people save the sun or moon from being eaten (by an eclipse) or when they pray for rain in a drought, or when they decide an important matter only after divination—this is not because they think in this way they will get what they seek, but only to gloss over the matter. Hence the prince thinks it is glossing over the matter, but the people think it is supernatural. He who thinks it is glossing over the matter is fortunate; he who thinks it is supernatural is unfortunate.

It is difficult for me to decide, from the following passage,

[8] H. H. Dubs, The works of Hsüntze, (trans. from the Chinese with notes), London Probsthain, 1928, p. 336.

[9] Idem, *op. cit.*, pp. 175 *f.*

[10] Quoted from H. H. Dubs, *op. cit.*, p. 181.

whether Hsüntze's theory of knowledge is purely empiristic, like that of Aristotle, or purely nativistic, like Plato's. Hsüntze [11] says: "A man from birth has the capacity to know things; this capacity to know things has its collected data (the apperceptive mass or the items of memory); these collected data are what are meant by stored away impressions." The tendency seems toward pure empiricism. This empiristic interpretation is strengthened by what follows: [12] "Moreover he has that which may be called emptiness. That which does not allow what is already stored away to injure that which is about to be received is called the mind's emptiness." But in another place, the emphasis seems to be toward nativism or at least innate mental categories as indicated in the following passage.[13] "The mind from birth has the capacity for knowledge; this knowledge contains directions; these directions consist of, at the same time, perceiving more than one thing." The following is also of interest in this connection: [14] "When the mind sleeps, it dreams; when it takes its ease, it indulges in reverie; when it is used, it reflects. Hence the mind is always in motion." Might not this have been written by William James or might not he have extended and amplified this germ of an idea into his concept of the 'stream of consciousness'?

But this further quotation [15] again tends toward the purely empiristic basis for the theory of knowledge.

Then by what means are similarities and differences found? The means are the senses given by nature. Whenever anything is judged to be the same sort or the same emotion, it is because the perception of the senses given by Nature is that the thing is the same. Hence, for example, the reason that similarities are universally recognized to be such everywhere is because their agreed upon names have become universal, and so they can be recognized. Form and colour are distinctions made by the eyes. 'Clear' and 'confused' sound, harmony, musical time and other sounds (noises?)

[11] Quoted from H. H. Dubs, *op. cit.*, p. 267.
[12] From Dubs, *op. cit.*, p. 267.
[13] Idem, *loc. cit.*
[14] From H. H. Dubs, *op. cit.*, p. 268.
[15] From H. H. Dubs, *op. cit.*, pp. 284 *f.*

are distinctions made by the ear. Sweet and bitter, salty and fresh, peppery and sour, and other flavours are distinctions made by the mouth. Perfumes and smells, fragrant and putrid, the smell of fresh meat and fetid smells, the smell of the mole-cricket and the smell of decayed wood and other smells are distinctions made by the nose. Pain and itching, cold and heat, smooth and rough, light and heavy, are distinctions made by the body. Doing things for a liking to do them and forcing oneself to do things, joy and anger, sorrow and pleasure, love, hatred, and desire are distinctions made by the mind.

The mind also gives meanings to impressions. It gives meaning to impressions and only then, by means of the ear, sound can be known; by means of the eye, forms can be known. But the giving of meaning to impressions must depend upon the senses given by Nature, each noting its particular kind of sensations, and then only can knowledge be had. When the five senses note something but do not comprehend it, the mind tries to give it a meaning but has no explanation; nobody would differ, everyone would call this ignorance. These are the means by which similarities and differences are found.

Nothing could be clearer and more definite than the emphasis upon sensory experience as the basis of all knowledge in the quotation above. We even have a distinction between process and meaning.

Hsüntze also notes differences in the clearness of sensory experience and he makes these differences in clearness the basis of the explanation of illusion. Hsüntze [16] states:

Whenever in observing things there is doubt and the mind is uncertain, then things are not apprehended clearly. When my thoughts are unclear, then I cannot decide whether a thing is so or is not so. When a person walks in the dark, he sees a stone lying down and takes it to be a crouching tiger; he sees a clump of trees standing upright and takes them to be standing men. The darkness has prevented his clear sightedness. The drunken man crosses a hundred-pace wide aqueduct and takes it to be a half-step ditch; he bends down his head when going out of a city gate, taking it to be a small door—the wine has confused his spirit. When a person sticks his finger in his eye and looks, one thing appears as

[16] From H. H. Dubs, The works of Hsüntze, London: Probsthain, 1928, p. 274.

two; when he covers his ears and listens, a tiny sound is taken to be a big noise—the circumstances have confused his senses. So in looking down from a mountain, a cow looks like a sheep; but whoever wants a sheep does not go down and lead it away—the distance has obscured its size. In looking from the foot of a mountain, a ten-fathom tree looks like a chop-stick; but whoever wants a chop-stick does not go up and break it off—the height of the mountain has obscured its length.

There is much of interest in this quotation—illusion, the fallibility of the senses, perspective and the effects of alcohol. And very keen observation throughout it all!

Action, as in the Greek systems, has its basis in mental processes. There is a complete dichotomy of mind and body in which mind has the dominant role.[17] "The mind is the ruler of the body and the master of the spirit. It gives commands and all parts of the body obey. It itself makes prohibitions; it itself gives commands; it itself makes decisions; it itself makes choices; it itself causes action; it itself stops action."

The mechanism of action is explained by Hsüntze, who recognizes both unlearned and learned behavior. This may best be explained by the following quotation:[18]

In miscellaneous psychological terms, the essential factor at birth is man's original nature. That which at birth is produced by the concord of the Yin and Yang, whose essence is suitable for the stimulus and response relation, which is not produced by training, but exists spontaneously, is called original nature. The love, hate, joy, anger, sorrow and pleasure of original nature are called the emotions. When the mind selects from among the emotions by which it is moved—this is called reflection. When the mind reflects and can act accordingly—this is called acquired training. When reflection is practiced and man's powers are trained—this is called acquired character. To act for the sake of righteous gain is what is meant by having a proper occupation. To act correctly to justice (Yi) is good conduct. That in man by which he knows is called knowledge; that knowledge which corresponds to reality is called

[17] A. Forke, The world-conception of the Chinese: etc., London: Probsthain, 1925, p. 269.

[18] A. Forke, *op. cit.*, pp. 281 *f.*

wisdom. That in man which can be carried out is called ability. That which corresponds to what really can be done is called ability. An injury to original nature is called a defect. What one meets at the moment is called destiny. These are miscellaneous psychological terms; these are terms fixed by the later Kings.

Mencius and Hsüntze entirely disagree regarding the original ethical nature of man—Mencius insisting that it is fundamentally good and Hsüntze insisting that it is evil. The following quotation [19] briefly indicates the latter's concept of ethical motivation:

The nature of man is evil; his goodness is only acquired training. . . . Man originally possesses the desires of the ear and eye; he likes praise and is lustful. . . . Therefore to give rein to man's original nature, to follow man's feelings, inevitably results in strife and rapacity, together with violations of etiquette and confusion in the proper way of doing things, and reverts to a state of violence.

These early Chinese systems exhibit interesting similarities and differences with those of contemporary Greek thought. In both cases the psychological systems are developed, not primarily for their own interest, but rather to explain human ethical reactions. Both are essentially and basically empirical and both correlate psychological with physiological processes. Although lacking in some of the detailed descriptions found in the Greek systems, certainly the Chinese are very highly developed for this period of thought. Furthermore, both types of system emphasize emotion as a basic factor in motivation.

The differences are equally interesting. The Greek systems emphasize consciousness and the development of ideas while those from China tend to be more behavioristic in their approach or, at least, more strongly to emphasize reaction.

In the case of both the Greek and the Chinese systems, there is a basis of cosmological elements—four in the Greek systems and five in the Chinese. Although the basic four elements were adhered to in the matter of temperaments by the later Greeks, they, at variance with the Chinese, broke from the four categories elsewhere in their systems. Aris-

[19] A. Forke, *op. vit.*, p. 301.

totle, for example, posited five modalities of sensation. The Chinese, on the other hand, were completely ordered throughout by their five fundamental elements. This difference of treatment can be accounted for apparently because the number and nature of the elements in the Greek systems were largely only a matter of tradition; while in the Chinese systems their five elements became prescribed by law and gained authority by being incorporated into the religious systems. Hence in the Liki [20] we find the following:

> For when the Kings had regulated names, when they had fixed terms and so distinguished realities, and when this principle (Tao) was carried out and hence their will was everywhere known, they were careful to lead the people and so the people were unified. Therefore distinguishing words, and making unauthorized distinctions, thus confusing the correct nomenclature, causing the people to be in doubt and bringing about much litigation, was called great wickedness.

There is a moral in this for all modern makers of psychological systems. It is merely another example of how greatly the acceptance of specific fundamental categories—their number and their nature—will determine the form of the completed system.

[20] J. Legge, Chinese classics, Hongkong: Lane, Crawford Co.; London: Trübner, 7 vols., 1861–1872. *Cf.* especially *Liki.*

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THE EMOTIONS IN A NEW ROLE

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For fifty years the psychological tides have ebbed and flowed around the James-Lange theory of emotions, for, although the main contentions of this theory have failed to survive the tests of later research, it served to direct the attention of the psychologist toward the important part played by the viscera in emotional activities. Prior to James' hypothesis, theories of the emotions were the outgrowth of *a priori* philosophy, and the physiology of visceral activities was far removed from the realm of pure reason where, it was thought, all such theories must be evolved. The transition effected by James ushered in the new era of more exact experimental methods, an era that has succeeded in bringing to light many new facts concerning the viscera and their nerve supplies together with much information concerning the activities of the central nervous system.

Meantime, many new theories have been advanced to account for the strange intermixture of feelings, conscious states and visceral activities which constitute the emotions, but, in the opinion of the writer, no theory yet proposed has offered a complete and reasonable interpretation of all the facts concerned in these forceful reactions. It is not the purpose of the present article to point out the deficiencies of these various theories, but, rather, to present the emotions in a new and distinctive role.

Inasmuch as any theory of the emotions must take into account the visceral activities which, at least, offer important corollaries to emotional states, we will first present a brief résumé of the commonly accepted facts of the anatomy and functions of those parts of the nervous system involved in emotional activity.

II

The nerves that are functional in visceral activities comprise the sympathetic nervous system and parts of the central nervous system which have been aptly termed by Kempf, 'the autonomic system.'

Those portions of the central nervous system involved are separated both structurally and functionally into three divisions, the cranial, the thoraco-lumbar, and the sacral. The cranial division includes the thalamus at the base of the brain and certain tracts in the spinal system down to the nerve trunks of the fore-limbs. The thoraco-lumbar division embraces those tracts in the spinal system concerned with autonomic activities and lying between the nerve trunks of the upper and lower limbs. The sacral division includes the tracts of the autonomic system leaving the cord below the nerve trunks of the lower limbs.

The middle of these three divisions, the thoraco-lumbar, contains the nuclei of many cells whose axones make synaptic connections with the cells of outlying ganglia which constitute the sympathetic nervous system. This system comprises a bilateral chain of ganglia lying ventral to, and parallel with, the spinal cord, together with other smaller ganglionic groups distributed throughout the body trunk. The nerves of these outlying ganglia are widely distributed to the viscera. By means of them the eye pupil is dilated, the sweat glands outpour, the heart and lungs are accelerated, the arteries and arterioles are contracted to raise the blood pressure, glands discharge their secretions into the mouth, stomach, and intestines, the liver releases its stored sugars and the genito-urinary organs are stimulated. The adrenal glands alone, of the viscera, receive no nerves from these outlying ganglia.

In addition to this wide distribution of nerves from the sympathetic system, the cranial and sacral divisions send out direct tracts to the viscera including the adrenal glands, the function of these direct tracts being opposed to that of the nerves arising in the sympathetic system. In a general way, where the nerves of one division contract the organ, those of

the other control or inhibit the contraction. Cannon describes these complementary functions in the following manner.[1]

> By means of the general diffuse action of the sympathetic and the opposite particular action of the parts of the cranial and sacral autonomic supply, every variety of change is provided for. All the viscera can be affected simultaneously in one way or the other through increased or decreased tone of the sympathetic division. And any special organ can be separately affected one way or the other through increased or decreased tone in the special nerve of the opposed cranial or sacral division that is supplied directly to the organ. The sympathetic is like the soft and loud pedals, modulating all tones together; the cranial and sacral autonomic are like the separate keys.

III

Pagano,[2] as early as 1906, adduced evidence which has later been corroborated by the careful experiments of Head, Cannon, Britton, Bard and others, to demonstrate that the nerve impulses controlling the visceral organs originate in the thalamus at the base of the brain. The cortex is apparently unable either to inhibit or control visceral reactions and such reactions have been observed to proceed in animals even after the cortex of the brain has been extirpated. The thalamus is the older part of the brain in phylogenetic development and is, therefore, more subject to pattern activities that have been developed through the ages of racial experience than is the cortex, which is more specific and individual in its reactions.

The thalamus receives afferent fibres from all parts of the body and forms reflex arcs to the viscera. But these afferent tracts also have synaptic connections in the thalamus with the cortex. Motor tracts pass from the cortex directly to the skeletal muscles, but some of them are also associated with efferent visceral tracts in the thalamus. It is, therefore, possible for the brain to respond to any situation which confronts us by means of efferent visceral stimulation from the

[1] W. B. Cannon, Bodily changes in rain, hunger, fear, and rage, N. Y.: Appleton, 1929, p. 28

[2] *Archives italiennes de biologie*, 1906.

thalamus, or with more specific skeletal movements and postures originating in the cortex, or with a combination of visceral and skeletal reactions determined in both thalamus and cortex.

IV

During the long ages before the cortical centers of the brain reached their present ability to function, there was constant need for prompt reaction to meet the emergencies of life.

Such reactions as were successful in warding off impending dangers were selected through their greater survival values and the patterns of these activities became deeply imprinted in the neural pathways of the race. These pattern activities in the viscera have a definite function in providing man with the physiological means for sudden and excessive action. Whenever he was confronted by a situation demanding either fight or flight, emotions of anger or fear were aroused and their corollary visceral activities were immediately organized and put on a war basis. The adrenal glands released adrenin into the blood stream and the adrenin caused the liver to give up its store of blood sugar. Sugar banishes fatigue and provides renewed energy for physical activities. The heart beat was accelerated and the arteries contracted, raising the blood pressure. Blood was drained from the viscera into the extremities of the body which were thereby prepared for the extra exertion that might be demanded of them.

These visceral pattern activities which are our racial inheritance, have been the subject of much investigation in order to discover a variety of patterns corresponding to the conscious states in different emotions. We know that the conscious states in fear and anger are very different, but, so far as has been discovered, the visceral reaction patterns in the two emotions are the same.

It was a basic contention of the James-Lange theory of emotions that the conscious state was determined by the visceral activity. If this be true, there must needs be a difference in the reaction patterns for such emotions as anger

and fear. Failure to find such differences in visceral patterns does not, necessarily, disprove the theory, for they may yet be found. But, it is significant that we have only to reverse the sequence insisted upon by James in order to make a difference in visceral reaction patterns unnecessary. For, while two different conscious states could not be expected to arise from the same type of visceral reaction, on the other hand, the same visceral pattern might easily be conditioned by different conscious states. And, while there are many other cogent arguments against the James-Lange theory, the one here presented certainly indicates that there is something wrong with the sequence he sought to establish.

V

The condition that led James to reverse the older sequence in emotions was that unless the visceral activities determined the conscious state, "the latter would be purely cognitive in form, pale, colorless, destitute of emotional warmth. We might then see the bear, and judge it best to run, receive the insult and deem it right to strike, but we should not actually *feel* afraid or angry."[3]

This difficulty, however, may be resolved in another manner and without any such change in the sequence as was made by James. In order to set forth this new view of the emotions, we will begin with the perception of a situation that involves emotional activity. The perception that arouses visceral activity may differ but slightly from one which results in some simple type of adaptive activity involving no emotional content. Ward, in a criticism of the James-Lange theory, clearly presents this difference.

"Let Professor James," he says, "be confronted first by a chained bear and next by a bear at large; to the one he presents a bun, and to the other a clean pair of heels."[4]

Whenever a situation involving a menace to life, liberty or well-being confronts us, it is liable to arouse an emotional state. But a similar situation, that is robbed of the menace

[3] W. James, Principles of psychology, London: Macmillan, 1901, vol. II, p. 450.
[4] Article on Psychology, *Encyclopaedia Brittanica:* 9th Ed.

either by some perceived condition or through our own confidence to deal with it, involves only a simple cortical response without emotional content. Emotion is aroused whenever the higher centers of the brain fail to provide a fitting response to the perceived situation, or when a doubt is aroused as to our ability to successfully respond to it. If the man who meets a bear at large has a gun in his hands and knows how to use it, his morale will not be shaken and his confidence in the outcome will inhibit both fear and visceral reaction.

Emotional reactions are inversely proportional to the ability of the higher centers of the brain to meet a given situation. A well turned response will inhibit the blush of modesty suffusing the cheeks of a maid. We weep in sorrow because we can think of no specific activity adapted to the situation that has caused our sorrow. If we strike a man who has insulted us, our anger vanishes with the blow, and we pick him up and dust off his clothes. Walk away without avenging the insult and the more we think of it the angrier we become.

VI

The physiology of the nervous processes involved in emotion may be readily seen from the application of a few facts and fundamental laws of nerve impulses. We now know that such impulses are electro-chemical in nature. They pass along the nerve tracts in one direction only and all afferent impulses are switched in the brain or spinal cord into efferent pathways. Nerve impulses consist of a number of successive waves and such impulses, arising in a receptor, proceed to the brain by virtue of a raised potential in each successive cell along the pathway; when the potential in any cell is sufficient, it discharges across the synapse between it and the next succeeding cell. Such an impulse cannot turn backward because it can pass in only one direction through the cell, and it cannot stand still, because the rise in potential causes it to flow onward; it may be blocked in only one way, that is when there is no pathway opened before it of sufficiently lower synaptic resistance to allow the impulse to discharge.

Afferent impulses from the receptors in all parts of the

body enter the brain through the thalamus and, in the thalamus, the impulse is directed toward the cortex. It will be remembered that afferent tracts from the receptors have synaptic connections in the thalamus with both the cortex and the viscera. The visceral pathways are always open to the passage of impulses; that is, they offer preformed pathways and are not subject to selection by the cognitive processes as is the case with the cortical pathways. These visceral pathways, therefore, must present a higher synaptic resistance than do the cortical pathways; otherwise, all impulses would result in more or less visceral activity, and there would be no such thing as a pure cognitive process.

It is reasonable to believe, therefore, that all afferent impulses are directed in the thalamus into cortical pathways. If the cortex fails to provide an efferent pathway for the impulse, the tract leading to the cortex becomes blocked and the potential of the impulse is raised so that the synaptic resistance of the visceral tracts in the thalamus is lower than the resistance in the cortical pathway. The oncoming waves of the impulse, therefore, are directed into the viscera.

The situation is like that of a stream of water flowing against a dam. When the gates of the dam are closed, the water mounts higher and its potential power, due to the raising of the water level, is increased. Now, if a side sluice is opened behind the dam, the water, on reaching the level of this channel, will discharge through it, and this discharge through the sluice will prevent any further rise in pressure at the dam. A nerve impulse in like manner, takes the path of least resistance. The viscera have a function, therefore, resembling that of a safety valve.

VII

Having analyzed emotional activity from the physiological point of view, we may now note some of its psychological implications. It was the rise in feeling tone in emotion that caused James to reverse the sequence of activities. From the point of view we have just developed, such a reversal is both unnecessary and misleading, in fact, it may well be

doubted whether the visceral reaction correlative with emotional states makes any contribution whatever to emotional feeling. *The blocking of the cortical pathway offers an all sufficient reason for the increased feeling tone of the perception.*

There is much in the theory here presented that substantiates Dewey's theory published a decade after that of James. He held that when an individual is faced with a situation to which he can find no ready way of reacting, the brain is cluttered with many different impulses and tendencies for expression. Dewey rightly insisted that "the mode of behavior is the primary thing and that the idea and the emotional excitation are constituted at one and the same time; that, indeed, they represent the tension of stimulus and response within the coordination which makes up the mode of behavior." [5] And he continues later with the query: "Does anyone suppose that, apart from our interpretation of values, there is one process in itself intellectual, and another process in itself emotional?" [6]

The theory we have stated integrates the various activities that have too often been separated into a single mode of behavior in which feeling is a natural concomitant. Moreover, we are now able to account for the qualitative differences in emotions. For *the original perception of the situation determines the character of our feeling regarding it.* If the situation confronting us engenders a doubt of our own ability to cope with it, our feeling is that of fear. A situation that offers insult to our pride, outrages our personal rights, or menaces our liberty, arouses the feeling of anger.

But, while there are certain similarities in emotional states that lead us to speak of them as anger, fear, sorrow, or happiness, emotional states are as various and as different as the situations that arouse them. What we really experience in emotion is the perception of a situation and this perception acquires a reinforcement of feeling due to our failure to provide an adaptive reaction. The emotion of fear, as commonly classified, covers a wide variety of situations implying doubt, lack of confidence in ourselves, superstition, fear, fright, the

[5] J. Dewey, The theory of emotions, PSYCHOL. REV., 1895, 2, pp. 18–19.
[6] *Ibid.*, p. 21.

mystery of the unknown, our inability to comply with social demands, the breaking of a known rule, custom, or law, and many situations that threaten our mental or physical well-being. And, because each emotional state is the result of a different concrete situation, it is impossible to make any definite catalog of emotional states. For this reason, every classification that has been made of these states is different and psychologists have found themselves in disagreement on everything except the broadest and most general fundamentals. The theory of emotions we have presented, sets aside these 'pigeon-hole methods of classification' in favor of a dynamic mode of behavior wherein feeling is subordinated to adjustment and expression.

VIII

In this process of adjustment, emotional behavior assumes a new role in human progress. Inasmuch as specific adaptive behavior is the aim of all education and training, the failure of definite responses to environmental situations which result in emotion, is always unsatisfactory. Emotion ever produces within us a spirit of unrest and dissatisfaction. When the emotion has passed, we are prone to think of the things we could and should have done. Emotion creates within us the demand for better adjustment and more efficient modes of expression.

In the dim dark ages before man had invented the sound symbols of speech as a means of expression for his feelings and ideas, the emotional toll must have exacted a terrific cost both on the body and mind. The visceral reactions that were built up to prepare him for the struggles of existence were his only means of bodily salvation. The father could not adequately teach his son how to meet the dangers of life. Each one had to learn through experience, and this was often fatal, for every experience was a test of his strength, agility and endurance. The force imparted by his visceral reactions was his chief reliance. With the advent of speech came a thousand additional safeguards. Men could teach each other, they could plan together the best means of attack and defense. Experience became communicable, and all because the dis-

satisfaction and unrest created by emotional response led to the devising of better modes of adaptation.

The man who first invented the javelin or the bow and arrow, which could kill at a distance, substituted cortical activities for visceral activities. Had he been satisfied with the results of the visceral activities which gave him added physical power, there would have been no progress and every situation that confronted him would have resulted in a similar type of physical expression.

IX

Under the progress of cortical reaction, it is evident that the emotions no longer play the part in life that they did ages ago. The devising of weapons that could kill at a distance decreased the number and fatality of personal hand to hand encounters. We talk ourselves out of many situations that would otherwise result in personal combat. Emotional reactions of the violent type have been largely replaced by cortical action in thought, speech, and the better types of adaptive behavior. Will emotional states, then, gradually cease to be?

The answer to this question is to be found in modified emotional behavior rather than in the more pronounced expressions that have supplied the subject matter of this article. It is probable that but few of our adjustments are of the purely cognitive or the extreme emotional types. Cognitive reaction is generally accompanied by emotional tones that make life colorful and interesting. Dewey, in the article previously mentioned, stressed what he termed the 'teleological' side of these feeling states which he described as being generated by the "adjustment or tension of habit and ideal." The ideals we build up in our attitudes always keep well in advance of our active means of adjustment, therefore our response to the situations of life that confront us is seldom completely satisfactory. In any situation we fumble in our thought processes and usually select a mode of reaction that is, at best, to some slight degree inefficient. Hesitation and doubt, even though finally emerging in a fairly efficient response, give a momentary opportunity for the tension of blocked pathways to develop.

It may be argued that in the case of the more expansive emotions, such as joy and mirth, there is no such hesitation or tension. But, what could be more inefficient than laughter and the other usual expressions of joy. Such emotions are born of our inability to respond to the situation just as certainly as are anger and fear. Music and art, like speech, have brought about a variety of means of expression unknown to primitive man. They are means of response that offer relief from more intense emotional states. But the arrangement of a musical composition may be designed to produce intense emotion through presenting to the mind situations to which we cannot respond by behavior adjustments. Martial music is designed to produce visceral activities that will banish the fatigue of the march or lead to deeds of heroism in battle. A folk song would lead to no such response but might easily lead to contemplative sorrow. In either case there is lacking the ability for a direct and suitable response.

It will now be evident that what we have often termed a 'suppressed emotion' is in reality a suppressed behavior adjustment. Freud often reiterates the need for relieving emotional states by definite activities that are well adjusted to the situations involved. Insofar as one builds up modes of behavior, habits, and the ability to think clearly through familiarity with situations that may arise, he is freeing himself from the disturbance of the less satisfactory form of emotional behavior. An automobile driver may so thoroughly prepare his mind for all sorts of possible emergencies that when they arrive, he will act according to the mode already decided upon.

Emotion may be resolved only by the aid of activities that have their genesis in the higher centers of the brain. It is 'teleological' in that it looks forward to more efficient reactions and furnishes us with the urge to attain them. The emotions thus take an important place in the factors of evolution, for they have replaced a race of brawn with a race of brains.

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EMOTION AS RELATIVE FUNCTIONAL DECORTICATION: THE ROLE OF CONFLICT

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The fact that 'disturbing' ideational or perceptual stimuli are more specifically effective of increase in blood pressure than of change in other autonomic activities implies a unique dependence of the involved blood pressure mechanisms on cortical function. Yet notwithstanding this fact, it is only rarely that it has been found possible to produce a consistent rise in blood pressure by direct cortical stimulation. Furthermore, the known neural mechanisms of blood pressure control are subcortical rather than cortical, and practically all aspects of the blood pressure reaction may be elicited by afferent nerve stimulation in decorticate animals. If we but knew the mechanism by which 'disturbing' perceptual or ideational stimuli give rise to an increase in blood pressure, there is reason to believe that we should go far toward explaining the basic mechanism of ideo-emotional response.

The effectiveness of ideational or perceptual stimuli in the production of blood pressure has long been recognized. In 1877 Couty and Charpentier showed that meaningful stimuli such as threatening movements would produce a rise in blood pressure in curarized dogs. Weber (1910) reported that hungry anosmic curarized dogs showed a similar rise in blood pressure following the presentation of food. Kiesow (1895), Binet and Vaschide (1899), Weber (1910), and Gellhorn and Lewin (1913) observed marked blood pressure increase in man in conditions involving unpleasantness, fear, and fright. The significance of blood pressure change was further elaborated with the appearance of Cannon's 'Bodily changes in pain, hunger, fear and rage' (1915). In this and later papers

* Studies from the Institute for Juvenile Research, Paul L. Schroeder, Director, Chicago, Series C, No. 257.

on the 'emergency function' of the sympathico-adrenal system, the presence of a menacing dog was frequently the effective stimulus for the increase of blood pressure and other symptoms of emotion in experimental cats. Following Cannon's early work Marston (1917) demonstrated the possibility of using intermittent readings of blood pressure as an indication of the physiological disturbance attending 'deception consciousness.' Larson (1922) and Keeler (1930) made further improvements in method and confirmed the diagnostic significance of blood pressure in truly disturbing deception situations where much is at stake.[1] A rapid rise in blood pressure was found by Landis (1926) in 'emotional upset.' Tigerstedt (1926) demonstrated an increase in students undergoing an important examination. Grollman (1929) showed that a professor's accusation of 'laxness' might also cause marked increase in students' arterial tension.

The writer's studies of blood pressure (1929) in combination with records of other physiological changes have shown that the continuous blood pressure record is affected by 'disturbing ideas' more definitely than any of the other easily recorded autonomic changes. Rowles and Patrick (1934) confirm this finding. Studies we have undertaken with Miss Heath (1932) and with Dr. Solomon (1934) provide further verification and elaboration. By way of contrast we have found that peripheral changes, the galvanic skin reflex, for example, discriminate much less clearly between disturbing and indifferent ideas, and are relatively more specific for sensory stimuli and the concomitant reactions of preparation by which the organism is mobilized to a state of alertness.[2] It seems clear that, whereas the palmar

[1] In contrast with these findings is the fact that Landis and Guilette (1925), Landis and Wiley (1926), and Larson and Haney (1932) found blood pressure quite unreliable as an indicator of deception in artificial laboratory situations where little or nothing is at stake. In similar artificial situations where both blood pressure and galvanic changes were recorded the writer has found the galvanic changes much the more reliable of the two.

[2] See Darrow (1933) and Darrow and Freeman (1934). A summary of evidence on this point is being presented separately. Briefly, increased palmar sweating (and high palmar conductance) is of adaptive value in that it provides improved grip on objects and increased tactual acuity. The palms are dry and conductance is low in sleep,

galvanic changes are most frequently symptomatic of the mobilization of mechanisms concerned with acquired adjustive activity, the presence of an appreciable blood pressure increase is generally identifiable with some disturbing or disrupting influence.

The excitation of mechanisms causing increased blood pressure and other symptoms of 'emotion' following disturbing ideational stimuli is apparently dependent upon some activity within the cerebral cortex, for it seems unlikely that any other brain structure is organized to differentiate between the meanings of perceptual patterns such, for example, as those involved in 'disturbing' and 'indifferent' verbal stimuli. But notwithstanding the part apparently played by the cortex in the discrimination of stimulus patterns, the immediate mechanism of 'emotional' excitation and concomitant blood pressure and other symptoms of activity in the sympathico-adrenal system is definitely subcortical. This may be concluded first from the fact that subcortical mechanisms become spontaneously active with the removal of cortical inhibitory control. Owsjannikow (1871), Dittmar (1873), Couty (1876), and more recently Woodworth and Sherrington (1904), Bazett and Penfield (1922), and Keller (1932) have demonstrated that large portions of the total emotional response may appear after the removal of higher centers as far down as the anterior borders of the midbrain. More limited reflex vascoconstrictor and cardioaccelerator fragments of the response were demonstrated by Cannon and Rapport (1921) after removal of all brain anterior to the medulla oblongata.

And still more important for present consideration is the finding of Cannon and Britton (1925) which showed that

while in alert activity the reverse tends to be true. Sweating and palmar conductance are increased by conditions which arouse the organism to a state of preparedness to respond. The cortical control of these palmar changes appears to be within the premotor area (Bechterew, 1905; Langworthy and Richter, 1930; Wang and Lu, 1930; Fulton, Kennard and Watts, 1934), the same general region which by recent evidence appears to be concerned in the coordination and control of complex motor adaptation, and initiation of manipulative activity (Wilson, 1908; Fulton, Jacobson and Kennard, 1932; Bucy, 1933).

the picture of emotion is relatively complete in the absence of the cortex and that without the higher centers almost any stimulus is likely to set off the complete gamut of excited emotional response. Bard (1928–1929) has demonstrated that the tendency and capacity for this relatively complete coordinated rage-like response remains after cerebral ablation stopping short of the caudal portion of the hypothalamus. Fulton and Ingraham (1929) were able to produce animals with similar behavior by limited lesions affecting assumed cortico-hypothalamic tracts immediately anterior to the hypothalamus. Karplus and Kreidl (1927) and many others have produced the symptoms of 'emotion', including increased blood pressure, by stimulation within the hypothalamus; Dusser de Barenne and Sagar (1931) produced a similar emotional state by hypothalamic implantation of strychnine. Ingram, Fisher, and Barris (1934) and Ranson and his associates (1935) have destroyed the capacity for emotional arousal by destruction within the hypothalamus, converting thereby erstwhile 'wild' monkeys into temporarily docile ones. In man there is frequently observed emotional manifestations in the excited early stages of anaesthesia. It seems clear that the immediate mechanism of excited emotional response is definitely subcortical (hypothalamic?). The role of the cerebral cortex appears to be that (1) of differentiating stimulus patterns and (2) of maintaining an appropriate inhibitory control over subcortical mechanisms of excitatory response. Hughlings Jackson (1884) and Head (1921) provide early precedent for the concept of inhibitory cortical control.

The problem we face is why, in the normal person, certain ideas or patterns of stimulation tend to release activity in the subcortical automatic mechanisms, while others fail to do so. Attempts that have been made at explanation have thus far proved quite inadequate. To say that these subcortical mechanisms mediate inherited 'instinctive' responses of service in extreme emergency may help us in our teleological thinking, and yet be of little assistance in understanding the mechanism involved. To explain the effects as the

result of 'association' resulting from previous experience doubtless states what in many instances is a fact, but does not without considerable rationalization explain why in one situation, as for instance when a member of the opposite sex is present, an idea may prove 'disturbing' and at another time 'indifferent.' The concept of 'conditioning' is even more unsatisfactory and requires great deviousness and ingenuity to make it fit all conditions. It presumes that a stimulus has been presented (generally, frequently presented) along with other stimuli which produce the appropriate bodily effects. While conditioning or 'association' is doubtless frequently an important factor, more often than not it cannot be demonstrated to have happened. Indeed, we can even set up in the laboratory discrimination problems and reaction-conflicts in which stimulus words having no emotional history will nevertheless produce marked organic response. And finally, it is not necessary that our 'disturbing' ideational stimuli should tap some well of 'instinctive energy,' as for example by direct or symbolic reference to sex. In the case of the latter type of stimuli it is apparently the persistence of some 'tabu' or 'resistance' in the inter-personal relationship between subject and examiner rather than the specific character of the stimulus that occasions the 'emotional' reaction.

We may ask, then, what is the general nature of conditions essential to the production of the 'emotional' blood pressure response to ideational stimuli? In Couty and Charpentier's dogs there was a threat of injury. In Cannon's cats a hereditary (?) enemy was the stimulus. In Tigerstedt's and Grollman's students academic success was at stake. In those studies of deception where blood pressure has been found significant, life, liberty, or reputation is commonly in jeopardy. Deception unmotivated by demands of self defense is but poorly betrayed in the blood pressure records and much better revealed in the palmar sweat changes. Verbal stimuli were found characteristically productive of increased blood pressure in normal persons when those words were 'disturbing' or 'embarrassing.'

Furthermore, subjects in whom Darrow and Heath (1932) found that the warning of forthcoming electrical shocks produced the larger blood pressure increase answered Thurstone Personality Inventory items in a manner suggesting that they were "oversensitive regarding matters affecting the integrity and security of the 'self.'" "The concepts of mental 'conflict,' 'resistance,' and 'blocking,' possibly the products of conscious or unconscious fear" seemed to be applicable in those cases. In like manner 'irritability' and 'resistance' and 'blocking' in psychotic patients were frequently found by Dr. Solomon and the writer (1934) associated with large blood pressure and little or no galvanic change. And in recent tests of apparatus[3] giving blood pressure, galvanic, and respiratory changes along with Luria's (1932) verbalmotor symptoms of 'conflict,' the inferred dependence of ideationally increased blood pressure upon conflicts seems to be confirmed. Apparently blood pressure rise is relatively specific for those disturbing conflicting excitatory perceptual influences which may be conveyed by symbols or other stimuli involving a threat to the physical or intellectual equilibrium of the individual.

And in so far as the situation involves the perception and interpretation of some perceptual pattern as a 'threat' it seems not unreasonable to assume that the pattern is recognized as a threat *to* something. It seems likely that the things threatened are certain accepted patterns of thinking and acting and their corresponding patterns of cortical activity. Most often the accepted and established patterns which are threatened in excited emotion are those which have habitually represented and furthered the physical safety and comfort, the intellectual and social dignity and integrity of the individual. Sometimes, however, the threat to existing patterns may be effective without implication of a personal injury, as in cases where sudden great good fortune has been known to precipitate the symptoms of 'functional decortication.' Such threats to basic patterns of thought and behavior whether for good or ill are guaranteed attention and

[3] The behavior research photopolygraph, C. H. Stoelting and Co., Chicago.

demand action because they are to the individual the most important events in the world. They must, we believe, be the occasions of an active or *dynamic* intra-cortical conflict.

The hypothesis we set forth is that active conflict in the normal individual is frequently the essential condition for the release of the primitive automatic subcortical mechanisms of *excited*[4] emotion. We hold this to be the case (1) because there is little question that emotion-provoking perceptual patterns do release subcortical mechanisms from cortical inhibitory control, (2) because such perceptual patterns can be identified only by the cortex, (3) because the threat implied by perceptually induced ideational or cortical patterns, especially if the patterns are new, would necessarily be recognized only because of some incongruity or conflict with existing patterns, and (4) because a condition of intra-cortical conflict provides a rational mechanism for the release of subcortical functions from cortical inhibition.

That conflict is a common characteristic of emotion was early recognized by Dewey (1895) and the theme has since been elaborated upon by McLennon (1896), Kantor (1926), Howard (1928) and Luria (1932). These writers have emphasized the confusion, dissociation, 'blur,' disruption of behavior, destruction of equilibrium, and the competition between impulses typical of excited emotion. They look upon these as consequences or manifestations of the emotional state. Our emphasis on the other hand is on the fact that these outward manifestations are symptomatic of something taking place within the central nervous system, and more especially the brain, which we presume functions causally in precipitating emotion. Conflicting processes in the brain are conceivably of far reaching effect in directions other than in the mere production of conflicting motor impulses.

If conflict is, except in certain situations to be mentioned, essential to the release of subcortically controlled emotional

[4] The qualification of the changes as those involving 'excitement' appears necessary in order to distinguish these conditions from those in so-called 'emotions' of grief, sorrow, and remorse where a different mechanism from that here outlined is involved.

behavior, and if, as seems apparent, the cortex does, except in emotion, maintain a high degree of selective inhibitory control over subcortical primitive automatic mechanisms, the probable neural mechanism of release of emotion by ideas is at once suggested. True, we do not know the exact nature of cortical inhibitory control. Whether it is by means of a potential gradient, by the maintainance of volleys of inhibitory nerve impulses, by the inhibitory effect of interfering nerve frequencies, or by still other neural processes, can only be experimentally determined. The present hypothesis is that whatever the form of inhibitory control it is interfered with when perceptual patterns demanding or implying action conflict with patterns already identified with the individual's thought and action. It seems obvious that in conditions of active intracortical conflict there may be lessened (energy for?) control of subcortical functions and that the result is to set free the lower level activities. In other words, excited emotion may arise from a partial or relative *functional decortication* occasioned by dynamic cortical conflict. This does not necessarily imply unconsciousness. In fact, the person may be very much aware of the stimuli causing the disturbance. It implies only that the normal cortical liaison with subcortical mechanisms is partially broken. Perhaps the word 'excortication' would differentiate our usage, implying only the *relative* severing of cortical from subcortical functions.

Much evidence in favor of varying degrees of functional decortication of 'excortication' in emotional disturbances comes to mind. In the first place the non-voluntary and relatively automatic character of the activity in extreme emotion is a matter of common observation. In extreme emotion the individual does things which he is entirely at a loss to explain later. He may, as it were, appear merely as a bystander astonished at his own behavior. Overaction characterizes his movements. There may be a dysmetria, an absence of nice adjustment of the force of action to the needs of the act. Incoordination or asynergia may appear. Tremor and palsy may provide further indication of the

deficit in cortical control. Words may fail. The essential motor adjustments of complex acquired skills may be temporarily lost. The knowledge of what should be done in the particular emergency may be forgotten, especially if the emotional state precedes rather than, as often happens, follows, the essential learned adjustments. And so far as we can produce such conditions in the laboratory we have indication that there is an attendant increase in blood pressure as well as other evidence of sub-cortical release. When emotions overtake us outside the laboratory we still have ample evidence from sensations in the circulatory system and from observations of other symptoms that there has been a release of subcortically controlled function.

We do not, of course, imply by this formulation that all 'conflict' in the traditional sense occasions excited emotion. We have been careful to signify as essential conditions that the cortical patterns precipitating the conflict shall be occasioned by perceptual or ideational stimuli demanding or implying some action on the part of the individual. This limits the assumed condition within the nervous system to one of *dynamic* conflict. Furthermore, the conflicts with which we have been concerned are those imposed by the perception or ideation upon the pre-existing patterns, and especially those relating to self preservation in the physical, social, economic, intellectual, and other worlds. We have not been concerned here with possible conflicts between the opposing objectives of the individual where the implied conflict is not from forces outside. Nor have we been concerned with potential or latent conflicts as a consequence of presumed 'watertight compartments' of thinking or acting and involving no obvious dynamic process. It is apparently in these other senses that the concept of 'conflict' is often employed in psychiatry. Regarding the potential or suppressed conflicts we shall defer consideration.

Furthermore, it is obvious that all the manifestations of subcortically controlled response are not the direct result of ideationally induced cortical conflict. Clearly there is no cortical conflict mediating the response of the already de-

corticated cat manifesting 'sham rage' in response to minor sensory stimuli. There is possibly also no cortical conflict in animals, or even in man, in situations where certain stimuli, such, for example, as the sight or sound of a snake, set free a chain of 'instinctive' adaptive reactions. The number of situations taken care of in this automatic manner becomes progressively fewer as we advance upward in the scale of phylogenetic and cortical development, and as we progress in the evolution of self control. In man it seems not unlikely that such automatic responses, when they do occur, do not in themselves constitute 'emotion,' but that the emotional release which follows such stimuli occurs on afterthought when there has been time for the perception of the danger to *conflict* with the prevailing ideas of self conservation. How often are we alert and cool during an emergency which we have been trained to meet and 'emotional' when the emergency has passed! Strong sensory stimuli, especially if unexpected, may also sometimes release subcortical functions, apparently without the intervention of cortical activity. Attention to such stimuli, as they are about to occur, frequently renders them physiologically ineffective. Pain (see extensive review by Nysson, 1931) may apparently make its appeal directly to the subcortical mechanisms. Furthermore, it appears that once the subcortical mechanisms have been released, 'short circuiting' may continue subcortical control for some time after the occasion of the initial release has passed.[5] There are doubtless still other limiting circumstances, the specification of which would add to the usefulness of the present formulation. The determination of these qualifying conditions is at present an object of experimental study.

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[5] Such a persistence of the emotional response after the occasion for it has passed may be the basis of certain emotionally initiated neuroses. When the persisting symptom is only a limited fragment of the original total functionally decorticate response it may in some cases constitute a hysterical 'conversion symptom.'

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